

TAT TWAM ASI



EX BIBLIOTHECA INDICA
Dr. h.c. ALFRED SARASIN

THE HINDU MUSICAL SCALE

AND

THE TWENTY-TWO SHRUTEES

BY

KRISHNAJI BALLAL DEVAL
(Retired Deputy Collector).



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1910.

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INTRODUCTION.

The work accomplished by Mr. Deval, it would hardly be an exaggeration to say, marks an epoch in the history of Indian Music. As he tells us, many treatises have already been written on the subject, but those who have heard Indian Music and who have sufficiently keen musical perception to appreciate the smoothness and beauty of the intervals used, must have laid down some of those books after reading them with a feeling of bewilderment. If Mr. Deval's results are accepted, the Indian scale which is several thousand years old will stand out as the most perfect example of a natural untempered scale.

That Mr. Deval's 22 Shrutees are the correct ones may in the first place be presumed from the fact that he has studied the latest European literature on the subject of the formation of scales, and has spent eight years in testing the notes used by various singers in order to ascertain the exact intervals which the singers endeavour to produce. As he tells us, he has been guided by the principle laid down by old Indian writers on Music, that the simplest ratios are always the best.

Secondly it will be found that although Mr. Deval did not test his Shrutees throughout by the harmonic intervals 5:4, 6:5, and 7:6 which may be called the major third, minor third and septimal third, they are clearly built up from those intervals.*

* The major thirds.	The minor thirds.	The septimal thirds.
1. Sa : ti. ga.	1. Sa : K. ga.	1. K.ri.:ti.ga.(nearly)
2. a.k.ri : a.k. ma.	2. m.ri. : K. ma.	2. ti. ri. : a.k. ma.
3. K.ri. : K.ma.	3. ak. ga. : t.t. ma.	3. k. ga. : ti.ma. (,,)
4. ti. ri. : ti. ma.	4. ti. ga. : pa.	4. K.ma.:ak.dha.(,,)
5. K.ga. : pa.	5. K. ma. : k.dha.	5. t.t.ma.:m.dha.(,,)
6. K.ma. : m. dha.	6. ti. ma. : ti.dha.	6. k.dha.:ti. ni. (,,)
7. t.t.ma. : ak. ni.	7. pa. : K. m.	Exact septimal
8. pa. : ti. ni.	8. m.dha. : Sa.	sevenths.
9. k. dha. : Sa.	9. ak. ni. : k.ri.	1. k.ga. : ak. ri.
10. ak. ni. : m. ri.	10. ti. ni. : ti. ri.	2. pa. : ak. ma.
11. K. ni. : ti. ri.		3. k.ni. : ak.dha.
12. t.t. ni. : ak. ga.		

Indeed the importance attached to the Septimal intervals, that is those derived from the seventh harmonic, places the music of India in the first rank of intellectual developments of the Musical art. Some writers on Harmony have elaborated theories based upon the supposition that the Subdominant (corresponding with Komal Madhyam) and dominant seventh (that is, Atikomal Madhyam) are for all practical purposes the same note. No one who has attentively listened to Indian Ragas could entertain such an idea for a moment, as the septimal seventh is very much flatter than the ordinary seventh, the interval 7:6 being easily distinguishable even by the untrained ear from the interval 6:5.

The 22 Shrutees are as Mr. Deval points out a selection from the total number of Shrutees used in Indian Ragas and Raginis. Mr. Deval had not only to ascertain what Shrutees were made use of by different singers but also to pick out the 22 which might justly be considered essential. It was after his choice had been made that I had the good fortune of hearing of his researches. I then suggested that to perfect his theories an inquiry should be made into the nature of the Gramas and the musical constitution of the Ragas. The first inquiry he has completed. His paper on the subject makes out a good case for the proposition that the Gramas correspond with the registers of the human voice. The question of the Gramas is therefore purely a question of pitch. No complete scientific examination of the Ragas has yet been made. The subject is involved in great difficulty on account of the fact that musical science in India has been handed down from one generation to another mainly by oral teaching. The result is that no two singers can agree as to the intervals to be used in the Ragas and Raginis; even in the case of Ragas whose names are known to every Hindu household there are differences of opinion. Mr. Krishnaji Mahadev Gokhale of Miraj who makes

use of considerably more than 22 Shrutees has kindly sung over to me 83 Ragas and Raginis and given me the names of the notes used in them. It appeared to me that the extra Shrutees used were chiefly those necessary to give the exact septimal intervals in some of those cases which I have marked 'nearly' in the footnote. An additional 'Atikomal Gandhar' of 280 relative number of vibrations was also used but in one Raga only. Mr. Deval tells me that some singers use a similar septimal 'Atikomal Nishad'. The 'Atikomal Nishad' chosen by him is however a vital necessity as the fourth above Madhyam and if the Shrutees are to be restricted to 22 I am afraid one must give up these two septimal notes, pleasing though their effect must be acknowledged to be.

The intervals between each Shrutee and the next as given in Mr. Deval's table D are of no great significance. Perhaps some day a list of Ragas as sung by some great singer will be given showing the intervals between the notes used in each Raga. Such a list would show that the Ragas are built up scientifically from the major, minor and septimal intervals. The list in table D as I have observed is merely the sum total of the Shrutees used as essential notes in all the Ragas and Raginis, and it is of no practical interest to any one, to take an example, that Madhya Rishab and Tivra Rishab are separated by the interval 81:80. Madhya Rishab is used in some Ragas corresponding in tonality with our B flat major or D minor keys; Tivra Rishab is the fifth from Pancham and is used in other Ragas in the manner one would expect from that connection.

My examination of the Ragas is sufficient to satisfy me that it is quite incorrect to say that the feeling of tonality is absent from Indian music. The feeling of tonality is sometimes disguised by the pedal bass, and to European ears this is

a defect, but that the feeling is there is shown by the progressions used and in particular by the final cadence. Old Hindu theorists had a special name, श्रुत स्वर for the note on which a particular Raga should end.

It is noteworthy that primary harmonics beyond the seventh are not recognized. In European music with just tuning the nearest approach we have to a true seventh is the augmented sixth; with tempered tuning we continually use sevenths which depend for their validity not upon harmonics but upon their aesthetic effect. Those writers who discourse upon the 17th harmonic as furnishing the interval of the minor ninth and diminished seventh, are in my humble opinion dealing with harmonic fictions, for I find it hard to conceive that any reasoned and cultivated musical system should go beyond the seventh harmonic. I have heard an Indian musician sing a Raga which he called Shuddh Todi, and in which he made use of notes corresponding with F sharp, G, Septimal A flat and B. The effect was wonderfully pleasing. In another form of the same Raga, the ordinary A flat was used instead of Septimal A flat. The latter appeared to be an inferior combination possibly because the interval from Septimal A flat to B being nearly a minor third is easier to sing and smoother in effect than A flat to B which approximates to a Septimal third.

Mr. Deval's 22 Shrutees appear to throw considerable light on the question of the constitution of the Ancient Greek Modes and will, I have no doubt, prove of the highest interest to European Scientists. In his book on the "Sensations of Tone" Prof. Helmholtz expresses doubt whether the Greek Modes were built up from the relations of F or those of G, and he suggests that they may possibly have been built up from both. If the Komal notes of Mr. Deval's scale are taken with Sa and Pa, as in the scale which he calls the Indian Diatonic Minor Scale, a scale is obtained which is in all probability iden-

tical with the Doric Mode. If the identity is accepted, it follows (1) that B flat is the fifth above E flat and is a relation of G, (2) that A flat is the fifth above D flat and is a relation of F. It also follows that in the ancient scales until the time of Pythagoras, tuning exclusively by fifths or thirds was unknown, the simplest intervals, which are obtained by fifths and thirds combined, being used. It is only in a system like the European, where transposition from one fixed key to another, and extensive modulation is practised, that tuning by a long series of fifths, tempered or otherwise, is likely to lead to anything but confusion. The Indian Tivra scale substitutes F sharp for F and the fifth above D for the A in our major scale, thus producing the smoothest and most harmonious scale possible, one in which every note is in primary or secondary harmony with G. This scale appears to be identical with Syntono-Lydian Mode.

Indian Musicians owe a great debt of gratitude to Mr. Deval, for, now that the Shrutees are known, it will be possible to construct harmoniums which will be in tune with Indian Music. The tempered harmoniums now in use which have a painful effect upon Indian ears will then be discarded. I have no doubt that with the advent of properly constructed keyed instruments, Indian Music will enter upon a new era of progress and development, possibly in the direction of harmony, for harmony is already extensively practised in the form of irregular Arpeggios. This progress will be hastened by the invention of a simple musical notation; and for that purpose also Mr. Deval's researches will be of the utmost value.

Belgaum,
2/4/11.

E. CLEMENTS.

List of abbreviations.

Names of the seven notes of the Hindu Musical Scale. Corresponding European names.

				Old notation.	Tonic Solfa.
ष.	षड्ज	...	...	C	Do.
ऋ.	ऋषभ	...	...	D	Re.
ग.	गांधार	...	...	E	Mi.
म.	मध्यम	...	...	F	Fa.
पं.	पंचम	...	...	G	Sol.
धै.	धैवत	...	...	A	La.
नि.	निषाद	...	...	B	Si.

अ. को. अतिकोमल
को. कोमल
म. मध्य
ती. तीव्र
त. ती. तरतीव्र

Do not accurately correspond with European notation. See Preface pp. VI, VII and tables A. B. C. D *

* The author has followed the usual practice of calling षड्ज C. If षड्ज is taken to be F, the note to which it approximates in pitch, the Indian and European names may be made to correspond, अ. को. being translated 'low flat,' को. 'flat,' म. 'low,' ती. 'natural,' and त. ती. 'high.' Thus म. धै. would be 'low D,' त. ती. नि. 'high E,' ती. नि. 'E natural' को. म. 'B flat.'

ERRATA.

Page.	Line.	Incorrect.	Correct.
2	17	he	the
"	18	Mr.	Mr.
8	16	by the string	from the string
14	12	32	16 x 2
19	1		
"	3		omit
21	3	$\frac{3}{4} \times 12 \frac{1}{2} \times 1$	$\frac{3}{4} \times 12 \frac{1}{2}$
"	3		omit = 455
"	25	$1 \frac{1}{2}$	$1 \frac{1}{2}$
22	7		omit in = $\frac{1}{2}$ 1
23	6	Englia	English
27 Table B	9	F	Fl
27 Table B	10	को. पंचम	पंचम
28 Table O	9	Fl	F
"	10	F	Fsh.
30	14	Cents number	Cents, name & kind
31	17	मंडा	मंड
"	18	Ghasists	Ghasit
40	10	that that	that
41	14	The musical scale	The Hindu Musical scale
44	11	observes	observed
"	29	by the means	by all the means

PREFACE.

Two years ago I published a small brochure entitled " Music East and West " dealing mainly with the scientific value of the Hindu musical scale and the question of "*Shrutees*." But further study of the subject has enabled me to state more fully my humble views and hence the present pamphlet. I read specially Capt. Day's Book on " Music of Southern India " which was suggested to me by Sir J. W. Muir Mackenzie, the late Revenue Member of the Government of Bombay. He has a fine ear for Music. About 3 years ago I had an opportunity of explaining the subject to Sir J. W. Muir Mackenzie, when I laid before him my views, and practically demonstrated them with the help of Professor Abdul Kareem, an artiste of great renown on this side of India. I also perused with great interest and profit the late Mr. A. J. Ellis' paper on the " Musical Scales of the World. " Besides the valuable light thrown on the subject by these treatises I had also much and invaluable enlightenment from Helmholtz's " Sensations of Tone " a masterly work on the Science of music. The perusal of these and other works has served to strengthen the views previously held by me. The tables of Scales in the present brochure are almost entirely worked out afresh, and in some respects differ from those in the old pamphlet. In that work I had touched upon the question of *Shrutees* so far only as the Diatonic Scale of seven notes was concerned. In this brochure, I have arrived at a probable solution of the whole question of 22 *Shrutees*. The paper read in the Kirloskar Sangit Theatre on the *Shrutees* is incorporated in this pamphlet.

It should be remembered while reading this pamphlet that there are two kinds of tones—the tones of *the natural* scale

and those of the *tempered* scale. According to Blaserna the vibrations of these notes are as follows :—

Natural Scale or Just Major.

C	D	E	F	G	A	B	C
240,	270,	300,	320,	360,	405*,	450,	480.

Tempered Scale.

240, 269½, 302½, 320½, 359½, 403½, 453, 480.

It will thus be seen that the above two scales are quite different. When a European repeats the seven notes of the Modulator, Dho. (d); Ray, (r); Me, (m); Fah, (f); Soh, (s); Lah, (l); Te, (t); Dho, (d) he necessarily refers to the notes of the tempered scale, which is now universally used in Europe in vocal as well as in instrumental music. The Hindoo Musician who repeats the seven notes of the natural scale, refers to the natural scale which is given above. The notes in the natural scale are indicated by the letters C, D, E, &c., as has been done in Scientific Books, and not by the usual small letter Solfa notation to prevent ambiguity and confusion. I am, however, for the present concerned with the notes of the Hindoo Music and as such with the notes of the natural scale only, noted above.

The sharp and flat notes:—The sharp and flat notes of the tempered scale are the result of the sub-division of the interval between any two principal notes, into aliquot parts or equal divisions. Such is not the case with Hindoo Music.

The interval between C and D or between 24 and 270 vibrations or the length of wire between 32" and 36" is divided into 4 parts which, as measured by Ellis's cents, are not equal parts, but 85, 27, 70, 22 cents respectively. The notes making up these intervals are called अ० को० ऋ, को० ऋ, म, ऋ, गी० ऋ. The Indian word Komal must not be confused with

* Blaserna gives 400 as the vibrations of A, whereas our A is of 405 vibrations, which is exactly the Panchama or the 5th of D, vibrations 270.

flat, nor Tivra with sharp, nor must Atikomal be confused with double flat or Tivratar with double sharp. The nomenclature is quite different. As a matter of fact Tivra coincides with sharp in the case of only one note F sharp, and Komal with flat in the case of four notes D flat, E flat, A flat and B flat.

The formulæ embodied in the pamphlet, which have been deduced from rules laid down by Sanskrit writers, have been worked out for me by my learned and esteemed friend Mr. Nilkanth Vinayak Chhatre B. A., L. C. E., Fellow of the University of Bombay and retired Deputy Educational Inspector C.D. I take this opportunity of thanking him for the great interest he evinced in discussing the subject and suggesting several improvements. I must also express my obligations to my friends, Dr. G. K. Garde, the late Hon. Mr. V. R. Natu, Professor R. K. Joshi, late of the Fergusson College, Poona, G. S. Khare and others, who helped me much by their valuable contribution to the discussion of the subject.

I am extremely thankful to Dr. Hamilton who has a very fine ear and who very patiently heard my demonstration and encouraged me to continue my efforts in this line. Mr. Mac-Millan, Assistant Collector, Ahmednagar, kindly came over to Poona and very sympathetically went through the whole programme of the last demonstration which took place at the Kirloskar Theatre in Poona and made several valuable suggestions.

I cannot adequately express my gratitude to Mr. E. Clements, District Judge, Belgaum, who voluntarily and promptly extended his sympathy towards my efforts. He is educated in European Music and has also a very keen appreciation for Hindoo Music. He has not only written an intelligent introduction full of appreciation and suggestion but has improved this pamphlet in matter as well as in form and has thus made it intelligible to the European as well as to the

Indian public. Not only this, but Mr. Clements has suggested to me that there is a branch of Indian Music which requires scientific and systematic treatment on similar lines. He has convinced me that without the development of this latter branch, the present attempt will be incomplete. I allude to the composition of Indian Rag's and Ragini's and especially to their notation, a subject which I mean to take up as soon as I can.

SANGLI,
10-4-11.

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K. B. DEVAL.

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THE HINDU MUSICAL SCALE

AND

THE 22 SHRUTEES.

BY

Mr. K. B. Deval.

(Retired Deputy Collector.)

—————

For more than the last eighty years, several attempts have been made to determine the Hindu Musical Scale with mathematical precision, by Indian and European scholars. But hitherto they have not been crowned with success; the solutions arrived at do not satisfy the tests of reason. Neither do they agree with conclusions noted by Sanskrit writers on Hindu Music. Hence it is that I propose to lay before the public a few thoughts about the Hindu Musical Scale and the lines of its development and progress. It might be stated here at the outset that the Hindu Musical Scale dates as far back as the Brahman Period which is calculated, according to modern researches, to extend from 2500 B. C. to 1400 B. C. It is possible that further researches might modify this date or might, perhaps, carry it still farther back. But we may be certain that our Scale dates farther back than the Greek Scale which is acknowledged to be the parent of modern European Scales. Capt. Day in his "Music of Southern India" observes:—"The Historian Strabo shows that the Greek influence extended to India, and also that Greek musicians of a certain school attributed the greater part of the science of music to India." The antiquity of the Scale apart, the most important point to be noted about it is that it is formed in consonance with the laws of the constitution of musical sound. It is a progressive Scale and the lines of its progress are laid down in old Sanskrit works on Hindu Music. The ancient sages of India, with their austere methods of study, meditating for years together in the quiet and tranquil recesses of nature undisturbed by the bustle of human habi-

tations, have preserved the results of their labours in their precious works, which excite even to-day the wonder and admiration of the cultured world. In recent times the attention of educated Indians turned to this Art of Arts, and men like the late Mr. Kunte, Messrs. Pingale and Sahasrabuddhe, Mr. Banhatti, Raja Surendra Mohun Tagore, Mr. Chinnaswami Madliar, have written copiously on Hindu Music. But difficult as the subject is, several points have been enshrouded in mystery, *e.g.* the Shrutees. In some of these recent publications there appear misinterpretations of shlokas from the Sanskrit works. Hence they have given rise to a number of wrong notions about the Hindu Musical Scale, and consequently about the value of Hindu Music, not only among Indians but also among scholars of the West. European writers on Hindu Music *e.g.* Capt. Willard ("Music of Hindustan"—a paper sent to the Society of Arts in 1834), Sir William Jones (paper on Musical Scales), Mr. Bosanquet (paper read before the Royal Society of Arts in London in 1877 on the Hindu Division of the Octave), Mr. Patterson, Captain Day (Music of Southern India), Mr. A. J. Ellis (paper read before the Society of Arts in 1885 on the Musical Scales of the World), have come to hold erroneous views about the theory of the Hindu Musical Scale. This might be due partly to their ignorance of the Sanskrit works on Music, partly to the erroneous information supplied to them by recent publications, and partly to the assumption that the Hindus must have followed a system similar to the equal 'temperament' system at present in vogue in Europe. In 1885, the late Mr. A. J. Ellis, the distinguished English physicist, scientist, and translator and editor of Helmholtz's "Sensations of Tone", in his paper on "the Musical Scales of the World", after comparing and examining the Scales of the various nations—among them the Hindu Musical Scale also—came to the following conclusion:

"The Musical Scale is not 'one', not 'natural', nor even founded necessarily on the laws of the constitution of Musical sound so beautifully worked out by Helmholtz, but very diverse, very artificial, and very capricious."

This I humbly submit cannot be said at least of the Hindu Musical Scale, as will be seen from the following. Now as observed by Professor Pietro Blaserna, of the Royal University,

of Rome, in his valuable treatise on the "Theory of Sound in its Relation to Music", by a musical scale is meant "the collection of all the notes comprised between the fundamental note and its octave, which succeed each other and are intended to succeed each other with a certain pre-established regularity." "The musical scale is always the product of the musical activity of a nation extending over a number of centuries." Hence to allow such wrong impressions about the Hindu Musical Scale to stand permanently on record and to suffer them to prejudice the minds of Western and Oriental Scholars as to the rank which the Hindu Musical Scale should take in the musical scales of the world, is neither just nor reasonable when there exists abundant evidence to disprove the above allegations. To elucidate all the difficult points of so difficult and scientific a subject as Music requires an amount of labour, energy, and talent which is given to but a few; it is a stupendous task, and personally I feel it quite hazardous on my part to attempt to undertake it. But approaching the subject with the humility and diffidence of a student, I have pursued my attempts hitherto and I lay before the public the results of my humble labours.

2. It would be proper to state at the outset the laws of the constitution of musical sound which the ancient Sanskrit authors observed in their works on Hindu Music. In order to make this point quite clear, I place in juxtaposition the laws observed by Sanskrit writers and those followed by modern scientists of renown.

Both make a clear distinction between *Sound* and *Musical Sound*.

1. Sound.

European Scientists.

(a) Sound in our apprehension is that which is heard and therefore our only means of recognizing its existence is through the sensation on our ear. The auditory nerve alone can perceive sound.

(Holmes' Vocal Physiology—Ed. 1900—p. 52).

(b) Sound on the other hand is produced in our ears and is therefore subjective; but vibration is objective. It exists in sounding bodies independently of the listener. To a deaf man the vibration exists but the sound does not. Sound is the result of vibrations.*

Blaserna p. 27.

2. Musical Sound.

(a) Musical sound strikes us as being even, smooth and melodious like the tones of all musical instruments. Holmes p. 61.

Authors on Aryan Music.

(a) श्रुति or (नाद) श्रु = to hear
श्रवणयोग्या एव श्रुतयः ।

रागविशेष आर्या १४ टीका.

(b) श्रवणोद्भूतमाह्लात्वाद् ध्वनिरेव
श्रुतिर्भवेत्-विश्ववसु सं. र. पृष्ठ १४-

(c) प्रथमश्रवणाच्छब्दः श्रुयते न स्व-
मात्रकः सा श्रुतिः संपरिक्षेया
स्वरावयवलक्षणा ॥

माघ सर्ग १. श्लोक १० टीका.

also संगीत रत्नाकरः

(d) श्रुतिर्नाम = स्वरारंभकावयवः
शब्दविशेषः ।

माघ सर्ग १. श्लोक १० टीका.

(a) + (b) } May be translated
as follows :—
Any sound which
is heard by the ear
is a Shrutī श्रुति and
and a श्रुति and sound are
(c) + (d) } one and the same
and are perceived,
because the ear
hears them.

European Scientists.

(b) A note not accompanied by its harmonics may sometimes be sweet, but it is always thin and poor and therefore but little musical.

Blaserna p. 165.

(c) In order that a sound may acquire a musical character, it must satisfy the essential condition of being agreeable to the ear.

Blaserna p. 74.

3. Harmonics.

Harmonics defined.

Strings in vibrating do not only swing as a whole but have also several secondary motions, each of which produces a sound proper to itself. A string, when struck, vibrates first in its entire length, secondly in two segments; thirdly in three; fourthly in four, and so on. All of these motions are simultaneous and the sounds proceeding from them are blended into one note. The lowest note is the loudest and is called the fundamental or prime tone, and the others are called over-tones, upper partial tones or harmonics.

Holmes p. 69.

Authors on Aryan Music.

(b) श्रवणयोग्या अनुपनात्मकस्य
स्वराख्यस्य दीर्घध्वनेर्वर्तते.

रा. वि. आर्या १४ टीका.

(c) श्रुत्यन्तरभावी यः स्निग्धोऽनु-
पनात्मकः । स्वतो रंजयति
श्रोतृचित्तं सः स्वर उच्यते ॥

सं. र. स्वराध्याय प्र० ३ श्लो० २३.

स्वरशब्दस्य व्याख्यामाहः—
मनः श्रोतृचित्तं स्वतः कारणान्तरनिरपेक्षं
अनुरक्तं कुर्वतीति स्वराः.

रा. वि. आर्या १४ टीका.

In Sanskrit, *Harmonics* are
called अनुपनात्मकध्वनिः

(a) श्रुत्यन्तरभावी यः स्निग्धोऽनु-
पनात्मकः ॥

स्वतो रंजयति श्रोतृचित्तं सः स्वर
उच्यते ॥

सं. र. श्लोक २३

(b) अनुपनात्मको ध्वनिविशेषो-
यस्मात् संभवति तादृग्लक्षणा-
उदीयात्-तथाप्रथमतः बंधनीया.
रा. वि. आर्या १९ विवेक २.

(c) रणद्विराघटनया नभस्वतः
पृथग्विभिन्नश्रुतिमंडलैः (Harmo-
nics) स्वरैः ।

स्फुटीभवद्ग्रामविशेषमूर्च्छनामवे-
क्षमाणं महतीं सुहृद्गुहः ॥

माघ सर्ग १ श्लोक १०.

वायोराघातेन पृथक् संकीर्णं
ध्वनद्विः अनुपनोत्पद्यमानैः
स्फुटीभवंति... टीका.

* So does संदन (= vibration) exist to a deaf man and श्रुति (= sound) is the result of 'संदन's.

The above Sanskrit piece marked (c) translated by Sir W. Jones runs as follows :—

× × “Nārad sat watching from time to time his large Veenā (sonometre or monochord) which by the impulse of breeze, yielded notes that pierced successively the regions of his ear, and proceeded by musical intervals.”

Pingale's treatise, p. 251.

It need hardly be noted here that the great sage Nārad perceived these Musical intervals (otherwise called harmonics) as arising from the whole length of the wire set free to vibrate on its own account and creating natural nodes and ventral segments as distinguished from artificial nodes and segments which it is necessary to produce (as will be seen in the sequel) in the construction of the Musical Scale.*

* Nārada's Veenā is called ब्रह्मवीणा Page 22 of “Hindu Music” Gayan Samaja.

महती is the name given to the ब्रह्मवीणा of Nārada in the stanza quoted here.

Here we have in the clear poetic way of Magha, noted down a fact which ought to arrest our attention. Nārad is descending from the heaven to the earth and the wind strikes his *big lute* the Mahati. He was observing his instrument with the Murchhana of the several Gramas displayed or unfolded by the several Swaras (upper partial tones) each showing on the string its distinct successive ventral segments. Sir William Jones seems to have understood the word *Shruti* in the ordinary meaning of ear and not as the primary tone going to build up the secondary or upper partial or over tones. He interprets Mandala to mean regions or more scientifically, the encircling channels (of the ear). According to him the various Swaras pierced the various recep-

A string when rubbed is in a state of rapid vibration; at the extremities where it rests on two bridges, it appears to be at rest. But when the middle part is examined, it is found that the string loses its sharpness of out-line. It appears sensibly thickened and this thickening reaches its maximum at about the middle of the string which proves that each particle of the string performs a to and fro movement in direction perpendicular to the length of the string. Vibrations of this sort are called transverse. The most simple form of a vibration is that in which the whole string vibrates simultaneously in one single vibration. This effect can easily be obtained by *leaving the string quite free*. The note thus obtained is called the fundamental note. × ×

श्रुतिमंडले: Ventral segments and the consequent production of harmonics as defined by Blaserna were observed by Nārada in vibrating strings which were set free to vibrate by the breeze.

What an amount of patient and careful observation must have been bestowed in the time of Māgha when the poet could describe the celestial musician Nārada as having detected by his eyes and ears these ventral segments and harmonics!

Somanāth refers to harmonics in his रागविशेष. In Aryas 30 and 31 he gives their importance; he calls them स्वयंभू notes. स्वस्मादेव भवन्तीति स्वयंभुवः। And again in commentary to आर्या 34, he states मेरुगतस्वयंभूस्वरपंक्तिप्रामा-प्येन। स्वयंभू tones means harmonics or upper partial tones which

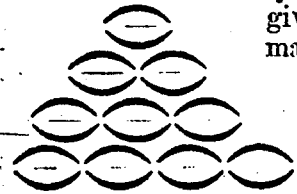
tive channels in regular order or succession. Whether we interpret the adjectival compound qualifying the Swaras in the Jonesian way or we do it in the method of Mallinath who draws out the meaning giving accurate quotations from works on Music, we can well understand that the Poet makes Nārada observe with amusement the action of the wind on the lute and note the same phenomena (Nodal points, Ventral segments and upper partial tones) as a modern European physicist may well observe with all the precision of his latest advanced notions of the theories of sound.

The foregoing interpretation of the Shloka has been accepted and found to be correct by Prof. V. G. Vijapurkar M. A., Prof. V. K. Rajwade M. A., Mr. Vinayakrao alias Annasaheb Patwardhan, Sardar K. C. Mehendale, Mr. Raddi Shastri of Elphinstone High School and other Sanskrit Scholars.

It would be interesting to note here that while Harmonics were unobserved by the Europeans as admitted by Blaserna till the latter half of the last century, it was a matter of common knowledge to the Hindoos at least as far back as the 6th century. Māgha makes a passing reference to it in his Sishupala-vadha which is a poem merely of general interest, which fact proves that in the days of Māgha general readers of poetic literature were expected to be familiar with the phenomena.

But if the string be touched in the middle, a note which is double in pitch, which practical musicians call the *octave* of the fundamental note, is obtained. The string in this case vibrates in two parts in such a way that the point touched remains at rest. This fixed point is called a node of the vibrating string and has been produced artificially by touching the string at the point indicated. Successively higher and higher notes can be obtained by the string by touching it at a third, a fourth, a fifth of its length, etc. etc.

(Blaserna, Chapter I, pages 11-14).



By the figures given in the margin Blaserna has shown the different modes of

vibration which a string assumes in different cases when it vibrates as a whole or into 2, 3, 4 &c. parts. In the first case no node is formed, in the others we have one, two, three, &c. nodes. The parts of the string between the nodes which contain these points of maximum movements are called ventral segments. This is what we have in श्रुतिमंडलैःस्वरैः of Māgha.

are heard when the whole string resting on two fixed bridges is made to vibrate. He warns musicians to always test the correctness of their notes, wherever possible, by referring them to these स्वयंभू harmonics.

ECHO—The best understood of all the cases of reflection is that which is called ECHO.

—Blaserna, page 43.

The reflection of sound has been utilized in various ways. Nature and art have combined to solve some problems not unknown in history. The celebrated “ear of Dionysius” is well known; it is a sort of hole excavated in the rocks near Syracuse where the least sound is transformed into a deafening roar. Similar phenomena are often met with under the large arches of bridges, viaducts, &c. &c.

6. Sympathetic Resonance.

Experiment shows that whenever a body vibrates, other bodies placed near it, are able to enter into a state of vibration on this condition only that such bodies shall be capable by themselves of producing the same note.

Blaserna, Ch. II, p. 49.

सं. र. पान ३५ कोहल.
आनंदस्य हि श्रुतीनां च सूचयन्ति
विपश्चितः ।

यथाध्वनिविशेषाणाममानं गगनोदरे ॥
टीका—तेषां अतिदृष्टमभागकल्पनयाऽमानम्.

(५) प्रतिध्वन्यवयवभूतध्वनिबहुत्व-
विवक्षयाऽऽनन्त्यं दर्शितम्

उत्तालपवनोद्देशजलराशिसमुद्भवाः ।

इत्यस्यः प्रतिपद्यन्ते न तरंगपरम्पराः ॥

रागविबोध, विवेक २, आर्षा ३२.

अष्टम्येकादशयोः सार्योरुध्वं समापर-
ध्वनितः ॥

ततैः समाः सपसमाः स्वयंभुवो मुक्ता-
तन्त्रीजाः ॥

टीका—ततैरिति ॥ × × मंद्रप मध्यसम-
मध्यमानां स्वयंभुवाद्धेतोः तैः मंद्र-
पंचमादिभिः समाः । सदृशनादाः मुक्ततन्त्री-
जाः मुक्ताः वामहस्तांगुलिश्रेणरहिताः याः
तन्त्र्यः प्रथमादयश्चतस्रः ताभ्यो जाताः
सपसमाः अनुमंद्रपइजातुमंद्रपइजमंद्र-
मध्यमाः स्वयंभुवः ज्ञेयाः इति शेषः ॥
नीचोच्चस्थानकृत एवैषां भेदो न रूपभेद-
इत्यर्थः ॥ रा. वि. वि. २ आ. ३२.

7. Pitch.

What is the limit of audible sounds? Does our ear perceive as a note any number of vibrations

According to Sanskrit writers there are five divisions of sound.

European Scientists.

whatever or is our perception confined between certain limits? Twenty or twenty-five vibrations just take place per second in order to produce appreciable note. The notes that are too low are badly heard and those that are too high are unpleasant.

Blaserna, pp. 66-67.

The well-known voice of a single singer embraces about two octaves. In the case of a woman a little more.

8. Laws of the vibrations of strings and of artificially produced harmonics.

Blaserna, pp. 71-72.

(1) When the whole string vibrates in one vibration, it gives its lowest note which is called the fundamental note.

If the whole string be touched in the middle with a finger, a higher note is obtained, which practical musicians call the octave of the fundamental note.

(2) If the string be divided by touching it with a finger or a feather into two, three, four, &c. parts, higher and higher notes are obtained which form that which is called "En-harmonic" series.

Authors on Aryan Music.

मत्तगमते तु-सूक्ष्मश्चातिसूक्ष्मश्च व्यक्तो-
ऽव्यक्तश्च कृत्रिमः = सूक्ष्मनादो गुहावासी
हृदये चातिसूक्ष्मकः &c. पञ्चानामपि सा-
मान्येन गीतोपयोगित्वे प्राप्ते इत्कंठ-
मूर्धस्थाने एव गीतोपयोगित्वमाह अत्र
गानार्हा इति ।

रा. वि. वि. १ आर्या ११.

एवं पञ्चसु त्रयाणां गानोपयोग्यता ।

रा. वि. आर्या १२-१३.

नादोऽतिसूक्ष्मः सूक्ष्मश्च पुष्टोऽपुष्टश्च
कृत्रिमः ॥

इति पञ्चाभिधां धत्ते पञ्चस्थानस्थितः
क्रमान् ॥ (९)

व्यवहारे स्वसौ त्रेधा हृदि मन्द्रोऽभिधीयते ।
कंठे मध्यो मूर्ध्नि तारो द्विगुणश्चोत्तरोत्तरः ॥ ७ ॥

सं. र. पान ३२-

मेरुभिष्टतुर्यतन्त्रीरवे सः = षड्जः
अभिव्यज्यते । अत्र तन्त्री शब्देन तदु-
द्भवो रवो लक्ष्यते ।

The whole vibrating length of the string resting on the two fixed bridges (मेरु) gives a note (षड्ज) which in English is called the fundamental note.

द्वाविंशतिः षड्जः द्विगुणसमः ।

रा. वि. वि. १ आर्या २१.

मध्यस्थानस्थः षड्जः = द्विगुणित-
षड्जः द्विगुणप्रायः

A note double of the funda-
mental is obtained, if the wire is
halved. [रागविबोध]-

European Scientists.

The notes of this harmonic series are not notes taken at random. They are very agreeable to the ear in relation to the fundamental note, and have great importance as we shall see in the sequel in the theory of musical instruments.

Tones increase in Pitch in the inverse ratio of the length of the Wire.

But it may be noticed that (in human voice) the larynx rises for the production of high notes.

9. Simple ratios of consonant notes.

It may be established as one of the fundamental principles of our music that the ear can endure notes, be they simultaneous or successive, on this condition-viz:- that they should bear simple ratios to each other in respect of the number of their vibrations per second, that is to say, that the ratio of the number of vibrations per second of the notes should be expressed by low numbers.

Blaserna. Chp. 5 sec. 2.

Authors on Aryan Music.

नीचोच्चस्थानकृत एवेषां भेदो न रूपभेदः
इत्यर्थः

रा. वि. वि. १ आर्या २१. टीका.

अत्यन्तरभावी यः स्निग्धोऽनुरणनात्मकः
स्वतो रंजयति श्रोतुश्चितं सस्वर उच्यते.

सं. र. आर्या २६-

अधराधरतीव्रा स्तास्तज्जो नादः श्रुतिमतेः
टीका-तन्व्योऽधराधरास्तीव्रा उच्चोच्चध्वनयो
भवन्ति.

तन्त्रीतंतुस्वरो ज्ञेयस्तद्द्वैर्ध्व्यस्तमानतः ।
तंतुस्थौल्येऽपि विज्ञेयस्तंतुसौक्ष्म्येऽप्यर्थं
विधिः ॥ शेष लीलावती-

यथा शरीरे श्रुतयः उत्तरोत्तरोच्चाः उ-
त्पद्यन्ते तथा वीणायां.

अधराउच्चा उत्पद्यन्ते-इति स्वारस्यम् ।
(सं. र. प्र. अ. प्रकरण १ श्लोक १३.)

वाद्यः सोपानपरंपराभिव आरोहात् अत्र
इत्कंठ मूर्धस्थानेषु मरुताघाताभि-
व्यक्तान्नादान् कुरुते = (विद्वणेति).
रा. वि. आर्या १३. टीका.

संवादि स्वराः Sanskrit writers call notes which bear simple ratios to each other संवादि स्वर and the following extracts will show the importance which has been given to these simple-ratio-bearing-notes (otherwise called संवादि स्वर) by the Aryan authors of music as a science, and by musical composers.

संवादिनां समाजो रंजनकारी भवेदिति
न्यायात् ॥

European Scientists.

Blaserna divides consonant intervals or simple ratios into 4 groups.

- 1 Unison or octave शुद्ध संवाद [रा. वि. वि. १ आ. २२].
- 2 Perfectly consonant संवादी.
- 3 Consonant अनुवादी.
- 4 Dissonant निवादी.

10. Beats.

When two notes not exactly of the same pitch and bearing intricate ratios are sounded together (a new phenomenon is observed known by the name of beats) a sound is obtained of varying loudness, now strong and now feeble, and very marked jerks or shocks are perceived. These shocks are the beats &c. &c.

If one of the two notes be slightly altered unpleasant beats are heard and they "spoil the harmony."

*Blaserna Chapt. V,
Sec. 4, 5 and 6.*

Authors on Aryan Music.

नितं निःशंकादिभिरिहापि संवादि
सामिध्यम् ।
रा. वि. १८.

The word न्याय may be translated by the English word 'law.'

टीका—संवाद=एककार्यत्वं येषामस्ति
तादृशानां समूहः (समाजः) सहावस्थितिः
इति यावन् रजनकारी रजको भवेत् इति
लोकप्रघातः ।

Shārangdeo also in his Sangit Ratnakar (संगीतरत्नाकर) defines consonant sounds and divides them into 4 classes.

सं. र. प्र. अ. प्रकरण ३ श्लोक ४९.

चतुर्विधाः स्वरा वार्धा संवादीच
विवाद्यापि ।

अनुवादीच वारीतु न्योगे बहुलः स्वरः ॥
सं. र. पा. ४९.

The Aryan and Sanskrit authors also describe in similar terms the unpleasant effect produced on our ear by the combination of notes bearing intricate ratios, which notes go by the name. विवादिस्वर एकभ्रुत्यंतरितो (having a difference of only one Shrutee or a quarter or a third of a note)

विवादिनो वैरिणौ मिथोभवतः ।

(आर्या ३८ रा. वि. विवे.)

टीका—विवादिनं लक्षयति—××
संवादि अनुवादिजनितरागरक्तिविना-
शकत्वात् विवादिनो भवतः । विवादिस्वं
ग्रथा—रूपमस्य गंधारः ॥

Two more resultant notes are also heard viz: 40 (64-24) and 28 (64-36); the last or rather the half of it viz: 14 introduces the septimal harmony in our music.

नित निःशब्दादिभिरिहापि संवादि
सान्निध्यम् ।

रा. वि. १८.

The word न्याय may be translated by the English word 'law.'

टीका—संवाद=एककार्यत्वं येषामस्ति
नोदृशानां समूहः (समाजः) सहावास्थितिः
इति यावत् रंजनकारी रंजको भवेत् इति
लोकप्रवादः ।

Blaserna divides consonant intervals or simple ratios into 4 groups.

1 Unison or octave शुद्ध संवाद
[रा. वि. वि. १ आ. २२].

2 Perfectly consonant संवादी.

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Shârangdeo also in his Sangit Ratnakar (संगितरत्नाकर) defines consonant sounds and divides them into 4 classes.

सं. र. प्र. अ. प्रकरण ३ श्लोक ४९.

चतुर्विधाः स्वरा वादा संवादीच

निवाद्यापि ।

अनुवादीच वादीतु न्योगे बहुलः स्वरः ॥

सं. र. पा. ४९.

10. Beats.

When two notes not exactly of the same pitch and bearing intricate ratios are sounded together (a new phenomenon is observed known by the name of beats) a sound is obtained of varying loudness, now strong and now feeble, and very marked jerks or shocks are perceived. These shocks are the beats &c. &c.

If
slightl
are he
harmoni

The Aryan and Sanskrit authors also describe in similar terms the unpleasant effect produced on our ear by the combination of notes bearing intricate ratios, which notes go by the name. निवादिस्वर एकश्रुत्यन्तरितौ (having a difference of only one Shrutee or a quarter or a third of a note)

निवादि note as defined by Shârangdeo पृष्ठ ४९ श्लोक ४९ टीका।

विषयनादिवादि । विषयं नाम वाद्या-
दिभिः स्वरैरुत्पाद्यमानरक्तैः विनाशकत्वं
(here रक्ति means harmony. रंजन
—pleasure &c. &c.)

11. Resultant notes or difference notes.

Blaserna in sec. 6 Chapter 5.

Whenever any two notes bearing simple ratios are combined, besides these two notes a low note is very clearly heard (i. e. when two notes making 200 and 250 vibrations per second are sounded, a third note corresponding to 50 vibrations per second is heard. This number is 4th part of 200 or the half of the half). This note is called the resultant or difference note. Its pitch or strength or the number of vibrations is equal to the difference between the two combined notes. This third note is agreeable to the ear, because it arises or is the result of two combined notes which bear simple ratios to each other. It, therefore, forms a consonant part of any one of the two notes combined and thus supports harmony.

"If then several notes be combined" observes Blaserna "it is not enough to select those which by themselves will give an agreeable harmony; it is necessary further to examine the resultant notes and to see how these will behave in relation to the combined notes."

After describing the Veenâ (a stringed instrument of the time of Nârada) the author of Râgavi-bodha in Arya 19 and in its commentary gives instructions as to how to tune the 4 strings on the said instrument.

अनुमंद्रषड्जमहेनुमंदि पं द्वितीयका तंत्री ।

मंदि संच तृतीया चतुर्थिका मध्यमं

मंदि ॥ १९ ॥

रा. वि. वि. २.

If translated it is as follows:-
The first string should be so tuned as to give the fundamental note. The second to give its 5th, the 3rd to give the octave, and the 4th to give F, the fourth of the octave. Now supposing the fundamental note gives 24 vibrations per second, we find out the following vibrational values of the 4 notes combined.

C or षड्ज=24
G or पंचम=36
C' or षड्ज=48
F or मध्यम=64

12
12
16

Now if we find out the values of the resultant notes they are as noted in the margin.

European Scientists.

The discovery of these resultant notes was made towards the middle of the 18th century and is generally attributed to the celebrated violinist Tartini.

Authors on Aryan Music.

This very same principle has all along been strictly observed both by the celebrated *Rishi Nārada* (who is called the father of music) during the Vedic period and also by instrumentalists and composers of subsequent periods.

× How the first two resultant notes form into the lower octave of the fundamental note $2^4 = 12$ how the 3rd note viz: of 32 vibrational value forms into lower octave of $F'' = \frac{9}{2} = 32$ and how these 3 support the original 4 notes and how they thus contribute to the harmony of the whole instrument, may be more easily heard and enjoyed than described.

The next most simple ratio that can be imagined after unison is that of 1 to 2. This is the ratio called that of the octave.

द्वाविंशत्यः षड्जः द्विगुणसमः पूर्व
षड्जेन । मध्य स्थानस्यः षड्जः ।
यथा पूर्वोक्तस्थापनया, मध्यषड्जेन-
सह मंद्रषड्जस्य मेरुस्थस्य संवाद
(agreement complete) साधुदेति
निश्चयः । रा. वि. वि. १ आ. २१, २२.

3. From the foregoing comparison of the fundamental laws of the constitution of musical sound, adopted by modern scientists, and those observed by our old Sanskrit writers, it will be clear that in constructing their musical scale the Aryan authors proceeded on scientific lines. How from these laws the Diatonic scale of seven notes, or the स्वरसप्तक was formulated may be noted below. It may be stated that the rule of perfect concord and of harmonics was strictly observed in the construction of the musical scale. An explanation of the ordinary terminology in Sanskrit musical works would help towards understanding the subject: मेरु=fixed bridge; moveable fret=सारिका; शुद्धसंवाद=unison or the relation

between notes bearing the ratio of an octave; सुख्यसंवाद=perfect concord, ratio of 2 : 3, अनुवाद = imperfect concord, ratio of 4 : 5 or 5 : 6; विवाद = dissonance. They lay down that the rule of perfect concord should be observed strictly in forming musical scales. The lengths which will be given for the several notes in the Diatonic scale below, are those of the wire of the Diachord, whose length, I take to be 36 inches; each inch being further divided into 20 subdivisions, which I call lines. I also take 240 vibrations for the fundamental note सा. In the Diachord are two strings or wires, resting on two fixed bridges, one at each end. When experiments are to be made, we have to tune one string to give out a note which may be called the fundamental note. The other string is to be tuned so that it may be in full unison with the first. When the two strings are thus tuned, then the moveable bridge is to be moved about for producing the required notes. Its height must be such as to leave no distance whatsoever between the string and the bridge, yet not pressing the string upward. One of the strings is to be left free to vibrate on its whole length, giving the fundamental note, while the different notes required are to be produced on the other. On moving the bridge to the distance required for producing a note, the string is to be pressed very lightly to the edge of the bridge with the finger-nail, so as not to increase the tension in the least. Then the exact note will be produced on sounding the string. To get the exact note on the given length, it is necessary that there should not be any disturbing element such as increased tension caused by pressing the string downward to the bridge. This depends on the accuracy of the instrument.

How the positions and vibrations of the 7 notes of the Diatonic Scale and the octave, have been settled with mathematical precision is shown below.

The Seven Notes: स₁ (c₁) to स₂ (c₂).

$l = 36''$											
Notes	(1)	(2)	(3) ^a	(3) ^b	(4)	(5)	(6)	(7) ^a	(7) ^b	(8)	
	O	D	E _a	E _b	F	G	A	B _a	B _b	C ₂	
प	ध	नी	स ₁	री	ग	म	प	नि	स ₂		
	36	32	28 $\frac{1}{2}$	28 $\frac{1}{2}$	27	24	21 $\frac{1}{2}$	19 $\frac{1}{2}$	18 $\frac{1}{2}$	18	0
Vibrations	240	270	300	303 $\frac{1}{2}$	320	360	405	450	455 $\frac{1}{2}$	480	
Ratios	1	9/8	5/4	4/3	3/2	2/1	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{8}$	2	

स₁ (C₁) and स₂ (C₂).

१. मेरुदिलद्वयुत्तरीस्वे सः षड्जः अभिव्यज्यते.

(रागविबोध-वि. १ आया २१).

Rule (1) *The whole length of the wire between the two fixed bridges gives the fundamental note स¹ (c¹).*

Let the length of the wire be 36'', the note produced be called स₁ (c₁) and let its vibrations be 240 per second.

२. मध्यस्थानस्थः षड्जः द्विगुणसम (रा. वि.)

Rule (2) *The note produced on half the length is in value equal to स₁ (c₁) and in pitch or vibrations it is double the fundamental note (F. N.).*

The note produced on the length 18'' is therefore स₁ or c₁ itself, but one octave higher. Let this note be called स₂ or c₂ to distinguish it from c₁ or स₁, the F. N.; then the vibrations of स₂ or c₂ are double i. e. $2 \times 240 = 480$ per second.

३. तंत्रीतनुस्वरो ज्ञेयः तद्वैद्यव्यस्तमानवः।

(शेष लीलावती)

Rule (3) *The pitch of a note or its vibrations are inversely proportional to the length of the wire.*

This rule is a legitimate inference from the above two rules. Rule (1) permits us to take any length for the Fundamental Note (F. N.) and according to Rule (2) if the length is halved the pitch is doubled, and if the length is doubled the pitch or the number of vibrations is halved. If therefore $\frac{1}{3}$ rd length is taken the pitch or the number of vibrations produced will be trebled. Or by generalization :

Rule (4) *The pitch varies inversely as the length and vice versa.*

The above four rules may therefore be put in the form of a simple Formula for convenience of working and ready reference.

Let V_n = Vibrations or pitch of the note on wire l_n inches long. u = The vibrations or pitch of स₁ (c₁) the F. N., here = 240

l = The length of the wire of the F. N., here = 36 Inches = 36''.

Then :

$$V_n \times l_n = u \times l \dots \dots \dots (A)$$

$$V_n = u \times \frac{l}{l_n} \dots \dots \dots (B)$$

$$l_n = u \times \frac{l}{V_n} \dots \dots \dots (C)$$

therefore if $V_n = 2u$

$$l_n = \frac{l}{2} \dots \dots \dots (D)$$

म (F).

४. मध्यस्थानस्थः मध्यमः। (रा. वि.)

उभयोः षड्जयोर्मध्ये मध्यमं स्वरमाचरेत्।

(संगीत-पारिजात.)

Rule (5) *The note म (For the fourth note) is produced at the middle of the Fundamental Note and its octave.*

The note म is therefore produced at half the length of स₁ (c₁) and स₂ (c₂) or at $\frac{1}{2}(36'' + 18'') = \frac{1}{2}(54'') = 27''$. In other words the note of the wire 27'' or 27'' inches of the executive part of the wire will give out the 4th note or म (F) and by Rule (4) formula (B) the pitch or vibrations of म (F) are equal to 320.

The formula (B) is :—

$$V_n = u \times \frac{l}{l_n}; \text{ Here } u = 240, l = 36 \text{ \& } l_n = 27$$

$$V_n = 240 \times \frac{36}{27} = 320 = \text{Vibrations of म}$$

And formula (C) is :—

$$l_n = u \times \frac{l}{V_n} \therefore l_n = 240 \times \frac{l}{320} = \frac{3}{4} l = \frac{3}{4} \times 36$$

or the length of म is $\frac{3}{4}$ of the length of the F. N. and the vibrations of म are $\frac{4}{3}$ of the F. N. and it may be laid down :—

Rule (6) *That the length of the wire of म (F) or the 4th note is $\frac{3}{4}$ of that of the Fundamental Note and the vibrations of म (F) are $\frac{4}{3}$ of the vibrations of the Fundamental Note स₁ (c₁).*

प (G).

९. त्रिभागात्मकवीणायां पञ्चमः स्यात्तद्विधिः । (संगीत-परिजात.)

Rule (7) *The fifth or प (G) note is produced on $\frac{1}{2}$ or $\frac{3}{4}$ of whole length of the wire. The former note is one octave higher than the latter.*

The length of the wire is 36''. Therefore a length of 12'' or 24'' will give the fifth note प (G). But we want the length between 18'' and 36''—the two limits of the octave. Therefore the length 24'' is that which we require and it will give out the note प (G).

Let us apply the formulæ (B) and (C) to the case of प (G).

$$V_n = u \times \frac{l}{l_n} \dots \dots \dots (B)$$

Substitute the values $u = 240, l = 36$ and $l_n = 24$

$$\therefore V_n = 240 \times \frac{36}{24} = 360 = \text{Vibrations of प (G)}$$

$$= u \times \frac{36}{24} = \frac{3}{2} u$$

or the Vibrations of प (G) are $\frac{3}{2}$ of its स₁ or F. N.

and

$$l_n = u \times \frac{l}{V_n} \dots \dots \dots (C)$$

$$\therefore l_n = \frac{240}{360} \times l = \frac{2}{3} l = 24$$

or the length of प is $\frac{2}{3}$ of its स₁ (c₁) or F. N.

These facts may be noted down under Rule (8) below :—

Rule (8) *The length of the wire of प (G) or the fifth note is $\frac{2}{3}$ of that of स₁'s (c₁) wire and its vibrations or pitch is $\frac{3}{2}$ of that of स₁ (c₁).*

री (D) and ध (A).

६. स-प-स-म-मुख्याः संवादिनः स्वराः एकसंश्रयाः प्रायः । (रा. वि.)

Rule (9) *In the interval of a given octave, स₁ (C₁) with प (G) and म (F) with स₂ (C₂) form perfect concords; it may be noted that स₁ (C₁) with म (F) and प (G) with स₂ (C₂), the inverted interval, form imperfect concords.*

This rule is very important and is made use of in finding out the lengths and vibrations of the other notes री (D), ग (E), &c. &c.

According to Rule (1) any length may be said to give the fundamental note and its पञ्चम will be the 5th note from it. This पञ्चम or प will form a perfect concords with it.* This gives us the following consonant notes.

F. N. स₁ (c₁).

स C₁

री D

ग E

म F

प G

स₂ C₂

Consonant note प (A) or म (F).

प G

ध A

नी B

स₂ C₂

री₂ D₂

प₂ G₂ or प G

* As I proceed to show, म₂ (E₂) is not a perfect pancham with प (A); nor is म₂ (F₂) with री (B).

Let us take ग (G) itself as the starting or fundamental note; then its पंचम or fifth will be ञ D in the higher octave which may be called र, D₂. Apply the formula (B).

$$V_n = u \frac{l}{l_n}; \text{ Here } u = 360, l = 24 \text{ and } l_n = \frac{2}{3} \times 24; \therefore l_n = 16$$

Rule (7). Substituting the values of u , l , and l_n

$$V_n = 360 \times \frac{24}{16} = 540.$$

540 are the vibrations of र, or र (D) in the 2nd octave. Therefore the vibrations of र in the first octave are $= \frac{1}{2} \times 540 = 270$
Vide Rule (2).

Formula (C) is—

$$l_n = u \times \frac{l}{V_n}; \text{ substituting } u = 240, l = 36 \text{ and}$$

$$V_n = 270, \text{ we have}$$

$$l_n = 240 \times \frac{36}{270} = 32. \text{ Hence—}$$

Rule (10) The length of र (D) is 32 inches and its vibrations are 270 or the length is $\frac{2}{3} l$ and vibrations $\frac{2}{3} u$.

च (A).

Rule (11) The length of र is 32". If we take this as the starting note, then its पंचम is च. Therefore the length of च is $\frac{2}{3}$ of 32 = 21 $\frac{1}{3}$ by Rule (8) and its vibrations are $\frac{2}{3}$ of 270 = 405.

ग (E) and नि (B).

The length of च (A) is 21 $\frac{1}{3}$ and its vibrations are 405. Let us take च as the fundamental note (Rule 1); then ग₂ (E) or ग, धार in 2nd octave becomes its पंचम or the 5th note (Rule 9). Therefore its length is $= \frac{2}{3} \times 21\frac{1}{3}$ and vibrations $= \frac{2}{3} \times 405$; but these are for ग₂. Therefore according to Rule (2) The length of ग is $= 2 \times \frac{2}{3} \times 21\frac{1}{3}$
 $= 2 \times \frac{2}{3} \times \frac{46}{3} = \frac{288}{3} = 28\frac{2}{3}.$

$$\text{and the vibrations of ग} = \frac{1}{2} \times \frac{2}{3} \times 405 = \frac{1215}{4} = 303\frac{3}{4}.$$

नि (B).

The length of ग is 28 $\frac{2}{3}$ and its vibrations 303 $\frac{3}{4}$ (Rule 12).

If we take ग as the Fundamental note, then नि becomes

its पंचम or the fifth note. Therefore the length of नि $= \frac{2}{3} \times 28\frac{2}{3} = \frac{2}{3} \times \frac{256}{3} = \frac{512}{9} = 18\frac{2}{3}$ and the vibrations of नि $= \frac{2}{3} \times 303\frac{3}{4} = \frac{2}{3} \times \frac{1215}{4} \times 1 = \frac{3645}{6} = 455\frac{5}{6} = 455\frac{5}{6}.$

ग (E) and नि (B).

again

Rule (12) If the vibrations of ग (E) be taken at 300 (and there is a reason for doing so) in place of 303 $\frac{3}{4}$ as obtained in Rule (2) above, then

$$l_n = u \frac{l}{V_n} \dots \dots \dots (C); u = 240, l = 36 \text{ and } V_n = 300$$

$$\therefore l_n = \frac{240 \times 36}{300} = \frac{144}{5} = 28\frac{4}{5}$$

Hence the length of ग = 28 $\frac{4}{5}$ and its pitch = 300.

[The ग (E) obtained by the foregoing process has 303 $\frac{3}{4}$ vibrations and bears with the F_n. Note a complicated ratio viz. 81 : 64. The ग (E) obtained as the fifth harmonic when reduced by two octaves has 300 vibrations and bears with the F_n. Note the simple ratio of 5 : 4; and it sounds more consonant with it. It is clearly heard on the bass string (the fourth, giving सर or F. Note) of the Vina. Sanskrit writers have adopted this in preference to the other. They tested their notes by harmonics; the author of रागविबोध clearly lays down : मेहगतस्वर्यंभूस्वरपंक्तिप्रामाण्येन । रा. वि. विवेक २ आर्षो १५ टीका.]

नि (B).

Rule (13) If ग (E) is taken as the fundamental note, then नि (B) becomes its पंचम the fifth in the same octave.

$$\therefore 300 \times \frac{2}{3} = 450 = \text{the vibrations of नि by Rule (8);}$$

$$\text{and the length is } \frac{2}{3} \times 28\frac{4}{5} = \frac{2}{3} \times \frac{144}{5} = \frac{288}{5} = 19\frac{3}{5} = 19\frac{3}{5}.$$

$$\therefore \text{The vibrations of नि} = 450$$

$$\text{and the length of नि} = 19\frac{3}{5}.$$

Notes and Summary.

1. The lengths and vibrations of सा₁ (c₁) and सा₂ (c₂) are directly derived from Rules 1-2-3 which are based on the directions distinctly laid down in old Sanskrit works on Music—रागविबोध, संगीत-पारिजात and संगीत-रत्नाकर.

2. Rule 4 expresses in the form of formulæ the results of the above rules. The formulæ which are derived from formula A are given below for the convenience of ready reference.

$$\left. \begin{aligned} V_n \times l_n &= u \times l \dots\dots (A) \\ V_n &= u \frac{l}{l_n} \dots\dots (B) \\ l_n &= u \frac{l}{V_n} \dots\dots (C) \\ l_n &= \frac{1}{2} l \dots\dots (D) \end{aligned} \right\} \text{ where } V_n = \text{Vibrations of the length } l_n \\ \text{where } u = \text{Vibrations of length } l, \text{ which} \\ \text{are respectively 240 and } 36''.$$

The rules are not discoveries of new truths in the science of the theory of Music. But they prove that these truths were known to Sanskrit writers on Music several centuries ago.

3. Rule (5) gives the length of ऋ (F) the 4th note as prescribed by रागविबोध. Rule (6) notes down the length and vibrational value of ऋ (F) as worked out from the rules.

4. Rule (7) determines the position of ऋ (G), the 5th note, its length on the diachord and its vibrations. Rule (8) notes down the length and vibrations of ऋ (G) the fifth note in general in any octave.

The positions, length and vibrations of स, (C₁), ऋ (F), ऋ (G) and स, (C₂), the 4 principal notes which have consonance of the first order, are thus marked down, worked out and settled. It now remains to find out the same of the remaining notes viz. री (D), ग (E), ध (A) and नि (B). This is done by the rule of संवादिष्व of the 5th note ऋ (G) which may be called the rule of perfect concord.

5. Rule (9) describes in full the rule of perfect concord and how it may be used in finding out satisfactorily every thing required to be known of the remaining 4 notes—री, ग, ध and नि.

6. Rules (10) and (11) show how the lengths and vibrations of री and ध may be found from those of ऋ (G) by applying the rule of perfect concord.

7. Rule (12) and (13) show how the lengths of ग (E) and नि (B) are determined, the first by imperfect concord with स, (C₁) and the second by perfect concord with ग (E).

8. The lengths and vibrational values of all the notes in an octave are thus found out, by means of rules distinctly laid down in old Sanskrit works on Hindu Music such as रागविबोध, संगीत-पारिजात and संगीत-रत्नाकर.

9. I give below Table A, the Diatonic Major Scale सत्र स्वर समक showing the number of Shrutees assigned to each note,† the number of vibrations, lengths of wire of the Diachord, the number of Mr. Ellis' cents,* the musical intervals between any two consecutive notes of the scale, the ratios of each note with the fundamental note, and the English names of the intervals and notes :—

10. Now on looking at this table it will be seen that there are three kinds of musical intervals viz. 8:9, 9:10 and 15:16. In the scale the interval 8:9 occurs three times, 9:10 occurs twice and 15:16 occurs twice. The seven intervals form two trichords : the intervals between स and रि, रि and ग, and ग and ऋ forming the first trichord ; while those between ऋ and ध, ध and नि, and नि and सं, forming the second trichord. Each interval of the first trichord exactly tallies with the corresponding interval of the second trichord. The interval between ऋ and ऋ (8:9) stands as a neutral zone between the two trichords. It is interesting to see that these intervals are evenly distributed. The interval between स and रि (8:9) which is the largest, occurs between ऋ and ध of the second trichord. The smaller interval between रि and ग (9:10) of the first trichord also lies between ध and नि of the second trichord. The smallest interval 15:16, which lies between ग and ऋ also appears between नि and सं (octave) of the second trichord. The total of Mr. Ellis' cents for these intervals is 1200.

11. Similarly we might note with interest the Diatonic Minor Scale (क्रोमल स्वर समक,) shown in Table B given below. It consists of eight notes including the upper Octave, like the Major Scale सत्र

† The assignment of Shrutees in Column 2, to the different notes is based on the following Aryā (आर्या) in रागविबोध (विवेक १. आ. ११):—

ऋषभस्तृतीयसार्या गःधन्वर्मा नवम्यां मः ।
पस्तु त्रयोदशीस्थः षोडशी, अष्टादशी च ध, नी ॥
द्वाविंशीस्थः षड्जो द्विगुणसमः पूर्वषड्जो ॥

For the explanation of the word श्रुति, I would draw the attention of the reader to Paragraphs 17 and 20.

° By dividing the interval between the fundamental note of value one (1) and its octave of double the value i.e. two (2), into 1200 cents, according to his method, Mr. Ellis has devised a system for measuring the various intervals. This system, into the details of which we need not go at present, he used for testing the scales of the world. It would be gratifying to learn that the Hindu Musical scale stands this test of cents admirably.

स्वर सप्तक. It will be seen that in place of major second ती. रि. and third ती. ध. and major seventh ती. नि., are inserted corresponding flat notes or कोमल स्वर. It is very interesting to note that the seven musical intervals are the same as those of the major Scale, but are differently distributed. So also are the ratios of each note with the fundamental note. The total of cents assigned to these intervals also comes to 1200. There are different modes (रग) and modulations (रागिनी) which are sung in the notes of this Diatonic Minor Scale.

12. It will be seen from the Diatonic Major Scale (Table A) that the smallest interval is 15:16 that between ग and म, and नि and स; and this interval is used in forming our Chromatic Scale of twelve notes. Perhaps here a question may be asked as to why this particular interval of 15:16 is used in formulating the chromatic scale of twelve notes. To this question the simple answer is as follows. When we look at the seven musical intervals of the Diatonic Major Scale we find that out of these seven, five are large intervals and two are the smallest viz. those of 15:16 between ग and म, and नि and स. Sanskrit writers have termed the musical Scale as "a ladder"—सोपानपरंपरा (संगीतरत्नाकर, प्रकरण ३, श्लोक १३). They have formed out of this Diatonic Major Scale of seven notes a Chromatic Scale of twelve notes, by putting four more smaller notes or steps. They have also styled म, the fourth note or step of the Diatonic Scale, as कोमल; this is the smallest step of the musical ladder. Now it is evident that in introducing minor notes the smaller ratios or intervals will have to be utilized. Thus we get a method for developing our Scale by introducing minor notes.

13. Proceeding thus, while forming our Chromatic Scale of twelve notes, the smallest interval 15:16 is introduced between the four notes of the Diatonic Scale having larger intervals viz. 8:9 and 9:10. The interval between स and ती. रि. is 8:9. This is the biggest step. An interval of 15:16 is introduced between these two notes. Thus is obtained a third note called को. रि. with 256 vibrations, स being of 240 vibrations. Now स stands to को. रि. in the ratio of 15:16, and को. रि. stands to ती. रि. in the ratio of 128:135. Assigning Mr. Ellis' cents to these intervals, we get for 15:16, 112 cents; and for 128:135, 92 cents. The larger interval of 8:9 having

204 cents is thus split up into two smaller ones of 92 and 112 cents respectively, making a total of 204 cents. The same ratio 15:16 is again introduced in the second half of the scale between प and ध. And the results are similar. In this manner we have got को. रि. and its corresponding सवर्ग note (consonant) in the second half viz. को. ध. Again similarly we divide the larger interval of 9:10 as before by the introduction of a smaller one of 15:16. Thus we get को. ग. of 288 vibrations, ती. ग. being of 300 vibrations. The interval between ती. रि. and को. ग. becomes 15:16, and has 112 cents; and that between को. ग. and ती. ग. becomes 24:25 and has 70 cents. These two smaller intervals make up the 182 cents which was the number for the second larger interval of 9:10. Similarly we have introduced को. नि. between ती. धे. and ती. नि., with 432 vibrations and having a ratio of 15:16 with 112 cents. The interval between को. नि. and ती. नि. is 24:25 with 70 cents. Thus we have in place of the seven notes of the Diatonic Scale, or eight including the upper octave, the following twelve notes of the Chromatic Scale viz. 1 स + 2 रि + 2 ग + 1 म + 1 प + 2 ध + 2 नि + 1 स = 12. Between म and प which with स form the backbone of our scale, we insert a note called ती. म. This note is the 5th harmonic of स and therefore forms अनुवाह with it. स and प are kept fixed and unchangeable. [षड्जपञ्चमयोरविकृतत्वात् । विदे गु. नि. नि. ३ आर्षा < टीका.] Now by inserting smaller intervals of 15:16 between the larger ones of 8:9 and 9:10, we have introduced four कोमल or flat notes into the two trichords or halves of the scale, two in each; making in all eleven intervals for 12 notes. In order to show that these intervals are just and mathematical, Mr. Ellis' cents are given, and each interval is given its English name. The total of these cents for the various intervals is 1200. These are the very notes of the Chromatic Scale of twelve notes which we actually sing and play. It is to be noted here that the twelve frets which are fixed on the Satar (सतार) as अचल धात, are intended to give out the twelve notes of this Chromatic Scale and not any other. The foregoing results are given in Table C.

TABLE A.

संगीत स्वरांचे स्वर-सप्तक (वरील षड्ज धरून आठ स्वरांचे) Indian Diatonic Major Scale.

1	2	3	4	5	6	7	8	9	10	11
Serial No.	Shruties.	Names of Notes.	Vibra- tions.	Musical Interval.	Its name.	Ratio of each note with the Funda- mental Note.	Its name.	Its name.	Vibrating length of wire required for each Note.	Inches-lines
1	0	षड्ज or C	240	8 : 9	Major 2nd	204	8 : 9	Major 2nd; 9th Har- monic ...	36	
2	3	ऋषभ or D	270	9 : 10	Minor 2nd	182	4 : 5	Just Major 3rd; 5th Harmonic ...	32	
3	5	गांधार or E	300	15 : 16	Diatonic Semitone	112	3 : 4	Just and Pythagore- an fourth ...	28-16 lines	
4	9	मध्यम or F	320	8 : 9	Major 2nd	204	2 : 3	Just and Pyth. Fifth 3rd Harmonic...	27	
5	13	पंचम or G	360	8 : 9	Major 2nd	204	16 : 27	Pythagorean major 6th; 27th Harmonic.	24	
6	16	धैवत or A	405	9 : 10	Minor 2nd	182	8 : 15	Just major 7th; 15th Harmonic ...	21-6 2/3 lines	
7	18	निषाद or B	450	15 : 16	Diatonic semitone	112	1 : 2	Octave ...	19-4 lines	
8	22	षड्ज or C'	480			1200			18	

कोमल स्वरांचे स्वर-सप्तक (वरील षड्ज धरून आठ स्वरांचे) श्रेणी थारावचे. Indian Diatonic Minor Scale of 5 flat notes
or 8 notes including the Fundamental, note the Fifth and Octave.

1	2	3	4	5	6	7	8	9	10	11
Serial No.	Names of Notes.	Vibra- tions.	Musical Interval.	Its name.	Ratio of each note with the Funda- mental Note.	Ratio of each note with the Funda- mental Note.	Its name.	Its name.	Vibrating length of wire required for each Note	Remarks.
1	षड्ज or C.	240	15 : 16	Diatonic semi- tone.	112	15 : 16	Diatonic semitone.		36	
2	को. ऋषभ or D flat.	256	8 : 9	Major 2nd.	204	5 : 6	Just Minor 3rd	112	33-15	
3	को. गांधार or E fl.	288	9 : 10	Minor 2nd.	182	3 : 4	Just fourth.	316	30-0	
4	को. मध्यम or F.	320	8 : 9	Major 2nd.	204	2 : 3	Just fifth.	498	27-0	
5	को. पंचम or G.	360	15 : 16	Diatonic semi- tone.	112	5 : 8	Just minor 6th.	702	24-0	
6	को. धैवत or A fl.	384	8 : 9	Major 2nd.	204	5 : 8	Just minor 7th.	814	22-10	
7	को. निषाद or B fl.	432	9 : 10	Minor 2nd.	182	5 : 9	(Sometimes called acute.)	1018	20-0	
8	षड्ज or C'.	480			1200	1 : 2	Octave.	1200	18-0	

TABLE C.

1	2	3	4	5	6	7	8	9	10	11
Ref. No.	Name of Native	Village	Moskil Interval	Its name.	Ellia's coin.	Ratio of weight with the Fundamental coin.	Its name.	Weight	Ratio of weight with the Fundamental coin.	Remarks.
1	एक रुपय	240	15 : 16	Diamond seal.	112	16 : 16	Diamond seal.	112	33—15	
2	अध्याय रुपय	265	128 : 135	Small Llama.	92	204	Small Llama.	204	35—0	
3	एक रुपय	270	150 : 160	Diamond seal.	112	8 : 9	Major Indian.	204	50—0	
4	अध्याय रुपय	288	24 : 25	Small Seal.	112	182	Small Seal.	316	25—16	
5	एक रुपय	300	15 : 16	Diamond seal.	112	4 : 5	Small Seal.	388	27—10	
6	अध्याय रुपय	320	128 : 135	Diamond seal.	112	3 : 4	Small Seal.	450	25—12	
7	एक रुपय	377	15 : 16	Diamond seal.	72	204	Small Seal.	590	24—0	
8	अध्याय रुपय	380	15 : 16	Diamond seal.	112	32 : 45	Small Seal.	702	25—10	
9	एक रुपय	384	128 : 130	Small Llama.	112	2 : 3	Small Llama.	814	21—67	
10	अध्याय रुपय	405	128 : 130	Small Llama.	92	5 : 8	Small Llama.	906	30—0	
11	एक रुपय	432	15 : 16	Diamond seal.	112	16 : 17	Small Seal.	1018	10—18	
12	अध्याय रुपय	440	24 : 25	Small Seal.	70	182	Small Seal.	1088	10—0	
13	एक रुपय	450	15 : 16	Diamond seal.	112	8 : 15	Small Seal.	1088	10—0	
14	अध्याय रुपय	480	15 : 16	Diamond seal.	112	1 : 2	Small Seal.	1200	10—0	

The English names of the rivers in the table of Harmonics on

TABLE D.

(Referred to at page 30 para 9.)

Indian Chromatic Scale of twenty-two Notes, or the Shrutee Scale.

[illegible]

Note :—The Sanskrit writers have assigned names to each one of the two Shruties, indicating the particular emotion, (or रस) effected by the particular note. As the twenty-two notes for the twenty-two Shruties have now been included in the above Table, it is easy to assign the names. It will be seen that along with the musical consonance in the notes, there is also a correspondence of the emotions effected by them. Experts like Prof. Abdul Karim do actually sing these twenty-two notes, for several modes and modules.

The following notes are also used by experts, sr. sr. sr. of 280 vibrations which is the 7th Harmonic of sr. sr. of 420 vibrations which is fifth above sr. sr. sr. of 280 vibr. ; sr. sr. of 307 1/5 vibrations which is minor third of sr. sr. and it has its corresponding sr. sr. which is fifth above it ; sr. sr. of 345 3/5 vibrations which is third from sr. sr. These are used by some experts for some Rāgas. Twenty-two Shruties are generally accepted by almost all the systems of Indian Music. There are several systems, e.g. the Govharari, as sung by Abdul Karim, the Kandhari as sung by Ishambhatkar and Bhayashahel Joshi ; the Dagar and the Nohari as sung by Dr Alladitta and Gokhale brothers (who both are in the service of the Kolhapur Durbar) and several systems in the Karnati. All these systems accept the Sh, though the several advocates differ as to the combination of the several notes as well as the names themselves used in several Modes and Modules. I add that further research proves that the first and fourteenth are really septimal notes of 252 and 378 vibrations respectively and are therefore really "flattens" as the name *shatshrutis* indicates.

* Note for column 10—each inch is divided into 20 "lines."

9. Now when we look at the intervals newly obtained in our Chromatic Scale of twelve notes (Table C), we find that another interval smaller than 15 : 16 which we get in the Diatonic Scale, appears in its appearance twice, and that is 24 : 25. It must not be overlooked, because it is an interval lying between two consecutive notes of the musical scale viz. को. ग. and ती. ग. which form part of the Anonics. Therefore this interval has been considered as an important and the most suitable interval to be put in for the purpose of evolving a still finer scale. The same process which has been described above for the Chromatic scale of twelve notes, has been followed in developing the scale of twenty-two notes or श्रुति scale as defined in रागविबोध. For purposes of easy reference, Table D of the twenty-two Shrutee scale is given below, with the musical intervals, lengths of wire of the Diachord, Mr. Ellis' cents number of Shrutees 'degrees' (as called by Mr. Ellis), and names of the note etc.

10. From this table it will be seen that when the smaller interval of 24 : 25 having 70 cents, is put in between स (240 vib.) and को. रि (256 vib.), another note called अ. को. रि (250 vib.), bearing the simple ratio of 24:25 and having 70 cents makes its appearance. In the same way a third म. रि (266 $\frac{2}{3}$ vib.) appears between को. रि and ती. रि. Similarly two संवादि (consonant) notes are introduced in the second half of the scale viz. अ. को. ध and म. ध. It is to be clearly noted here that these notes अ. को. रि, को. रि, and म. रि, in the first half of the scale, and अ. को. ध, को. ध, and म. ध in the second half are called by सोमनाथ author of रागविबोध as विकृत स्वरस, and are recognised by him. [Vide श्रुति Table in Mr. Banhatti's बालसंगीतबोध, Pt. III, Page 16.] In the same way अ. को. ग. and त. ती. ग and the corresponding अ. को. नि and त. ती. नि have been introduced newly. It is already stated that like स, प is also to be kept unchanged (अविकृत); and the two are to form the back-bone of the scale. The interval between म and प which is the largest viz. 8:9, cannot therefore be neglected. Therefore the Aryan authors divided the same into four parts and assigned notes which are considered as विकृतीस or modifications of म and नोत of प [vide श्रुति Table in Mr. Banhatti's book.] These notes are अ. को. म., को. म, ती. म, and त. ती. म, having the intervals of 24:25, 128:135, and 125:128 respectively, with 70, 92, 42 cents respectively, making up a total of 204 cents which are

assigned to the higher interval of 8:9 lying between म and प. In this manner we have got 1 स + 4 रि + 4 ग + 4 म + 1 प + 4 ध + 4 नि + 1 स (upper), making up a total of 23 notes including the octave. These results are given in the following Table D.

11. All the lengths given for the notes in these tables are those of the wire of the Diachord and they must not be confounded, with lengths of strings of playing instruments, such as Been, Satar etc. The difference between the instrument fixing a scale like a Diachord and a playing instrument consists in this, that in the playing instrument the height of the strings or wires above the frets necessarily varies from one to five millimetres, as has been shown by Mr. Ellis in his examination, of several वीणाs and the श्रुतिवीणा of Tanjore sent to him by Cap. Day. Unless we leave some margin for height, an instrumental player cannot move the fingers from the different frets freely and with ease; and he cannot produce increased tension in order to have different shades, and मेंडा (mends) and घसिट (ghasits) required for different modes (राग) and modulations (रागिणी). But it is to be observed that when the player puts pressure upon the string when bringing it down to the fret, the increased tension due to the pressure must per force increase the pitch. But in preparing an instrument of scale, which is in other words a Diachord, we must not leave any height whatsoever between the speaking string and the moving bridge. Now when we have prepared the above scale, we are to note down the different speaking lengths of the different notes, on the wire of the Diachord. When an instrument player wishes to set the frets to the instrument to a particular scale, he must keep this Diachord by his side; and taking into account the tension caused by the pressure of his finger on the string, he must see whether the note on the playing instrument tallies exactly with that given out by the Diachord. He must also while practising attune his ear or voice to the different notes of the scale produced on the Diachord, and not the playing instrument; because the latter is likely to misguide him. So also while producing different विकृत स्वरस or modified notes by mends (मेंडा) on the same fret on his playing instruments, he must not deflect the string indiscriminately; he should

deflect it only to such an extent as will give him the exact note required, which will tally accurately with that given out in the Diachord. This can be attained only by long and patient study. Even gifted specialists like the late Bande Ali and his disciples Chunna and Murad, Bharkhat Ulla, Haidur Bux, Antubua Sadhale and Vishnupant Joshi (Pakhwajis) required years of constant practice to train their ears and fingers to get the exact notes with ease. The Diachord is the exact standard of measurement for accurately determining the musical scale; in other words it affords us a means to measure musical notes, just as we have the rain gauge, the thermometer, the barometer etc. But the playing instrument, unless it is played upon by a specialist, is not the standard by which the musical scale can be accurately gauged, as the skill of the player must be taken into account. The Sanskrit authors clearly intended this, as they distinctly state the exact divisions of the length of the wire, for producing the different notes viz. स, र, ग, प, and म. They do not obviously intend that there should be any height whatsoever between the speaking string and the moving fret. Had this been the case, then the laws laid down by them (given above) would have given incorrect results. They intended the construction of the musical scale.

12. After having thus obtained these scales, let us now consider the Shruti problem. Among notable recent writers who have attempted to solve the question, may be mentioned Mr. Bhavanrao Pingale, Mr. Balawant Trimbak Sahasrabuddhe, and Raja Surendra Mohun Tagore. I will consider the methods of Messrs. Pingale and Sahasrabuddhe, first; and then examine the Raja's method. They have taken it for granted that like vibration a "Shrutee" was the "unit" of measurement of the long interval lying between a fundamental note and its octave and that 22 Shrutis were 22 subdivisions of equal value. This is not the case. A Shrutee which is a sub-division of a note, may be a quarter or a third of a note &c. &c., according to the position it occupies in the interval between any two consecutive notes.

13. For the purpose of comparing the Shrutee Scale with the exact Scale (स्वर सप्तक) they divided the entire length of the executive part of the wire into 44 units. I quote Mr. Sahasrabuddhe. "If a

monochord" says Mr. Sahasrabuddhe "be taken and a space equal to 44 units be measured and the bridge shifted to this point, the string when struck will yield a note ; if we start with this note as the tonic or keynote and run through the *gamut* by shifting the bridge (the Sanskrit writers affirm) the following facts will be observed. Sa will be produced at the distance of 44, Ri at 40, Ga at 37, Ma at 35, Pa at 31, Dha at 27, Ni at 24 and Sa again at 22, but the latter Sa will be twice as intense as the former."

तेषां श्रुतयः क्रमतो वेदा रामा दृशौ तथाबुधयः ।
निगमा रहनाः पक्षावेवं द्वाविंशतिः सर्वाः ॥ १६ ॥
तुर्यायां सप्तम्यां तासु नवम्यां श्रुतौ त्रयोदश्याम् ।
सप्तदशीविंशीद्वाविंशीषु च ते स्फुटाः क्रमतः ॥ १७ ॥
× × × ×
द्वाविंशीस्थः षड्जो द्विगुणसमः पूर्वषड्जेन ॥ २१ ॥

रागविबोधः.

Mr. Sahasrabuddhe has based the above theory on the wrong interpretation and application of Aryas 16 & 17 and the latter part of Arya 21 of रागविबोध quoted above.

Exact Hindu Scale—C D E F G A B C
24, 27, 30, 32, 36, 40½, 45, 48.

Mr. Sahasrabuddhe's—Sā Ri Ga Ma Pa Dha Ni Sā
22, 26, 29, 31, 35, 39, 42, 44.

And now when actual comparison is made by finding the ratios of the fundamental note with each of the successive 7 notes of the Shrutee scale thus wrongly demonstrated, we find none of the notes (except the octave) bears those simple ratios which our Hindu Scale as well as the European exact scale bear. This is quite plain from the following comparative table.

Shruti scale as explained
by Mr. Sahasrabuddhe.

सा = $\frac{22}{11}$
रि = $\frac{26}{13}$
ग = $\frac{29}{14.5}$
म = $\frac{31}{15.5}$
प = $\frac{35}{17.5}$
ध = $\frac{39}{19.5}$
नि = $\frac{42}{21}$
सा' = $\frac{44}{22}$

The Hindu Exact
Scale.

C = 24 = 1
D = $\frac{27}{24} = \frac{9}{8}$
E = $\frac{30}{24} = \frac{5}{4}$
F = $\frac{32}{24} = \frac{4}{3}$
G = $\frac{36}{24} = \frac{3}{2}$
A = $\frac{40.5}{24} = \frac{27}{16}$
B = $\frac{45}{24} = \frac{15}{8}$
C' = $\frac{48}{24} = 2$

It is well-known that notes increase in pitch in the inverse ratio of the length of the wire. And applying this law, we easily determine the several lengths of the executive part of the wire which, when sounded, will give the 7 notes of both the Shruti Scale (Mr. Sahasrabuddhe's) and the exact Scale. These lengths are :—

Shrutee scale as explained by
Mr. Sahasrabuddhe.
सा = the whole length

रि = $\frac{22}{11}$
ग = $\frac{26}{13}$
म = $\frac{29}{14.5}$
प = $\frac{31}{15.5}$
ध = $\frac{35}{17.5}$
नि = $\frac{39}{19.5}$ or $\frac{11}{3}$
सा' = $\frac{42}{21}$ or $\frac{1}{2}$

Exact Hindu
Scale. (Table A)
C = the whole length

D = $\frac{9}{8}$
E = $\frac{5}{4}$
F = $\frac{4}{3}$
G = $\frac{3}{2}$
A = $\frac{16}{11}$
B = $\frac{15}{8}$
C' = $\frac{1}{2}$

It will be found that each one of the intermediate notes of the Shrutee Scale as explained above bears a complicated and rather higher ratio with the fundamental note and that none of the lengths shewn on the left side gives out notes which are obtained in the स्वर-सप्तक (Table A) and which we *actually sing and play*. But the fact is otherwise. Our artistes actually sing and play notes which bear simple ratios with the fundamental note.

14. Mr. Chinna Swami Mudliar M. A. of Southern India, wrote a large volume entitled "Oriental Music," but has left untouched the question of श्रुति or Shrutees as being a very complicated and intricate one. How the labours of Messrs. Pingale and Sahasrabuddhe, were not productive of successful solution, I have already shown above. Raja Surendra Mohan Tagore also attempted to determine the position of the twenty-two Shrutees. He divided the whole speaking length of the wire into two halves, the whole length giving the स or fundamental note and the half giving the स', the octave ; both these notes are correct. Again he divided the first half into two equal parts, each being one-fourth of the whole length. The first quarter (of the wire) he subdivided into nine equal parts calling each part a Shrutee. At the end of the ninth part is sounded a note म (at $\frac{1}{4}$ of the wire) which is correct. In the next quarter

of the wire he made thirteen equal subdivisions, each being also called a Shrutee. Thus in all he got the twenty-two Shrutees. Let us now see whether according to the Raja's apportionment we get the other notes correctly. Now there are three Shrutees for ती. रि. of the Diatonic Major Scale. (Vide. रागविबोध आर्या २० and २२). According to Raja Surendra Mohan Tagore's division, three Shrutees would mean three parts out of the nine equal parts in the first quarter of the whole speaking length of the wire ; the length of these three parts would come to $\frac{1}{3}$ part of the whole wire ($\frac{1}{4}$ wire divided into 9 parts, each part $= \frac{1}{4} \times \frac{1}{9} = \frac{1}{36}$; three such parts would mean $= \frac{1}{36} \times 3 = \frac{1}{12}$ part of the whole length). Thus the ती. रि. will be produced, on the $\frac{1}{12}$ part of the whole wire, according to Raja Surendra Mohan Tagore's method; i. e. ती. रि. will be produced on a length of 33 ($= \frac{36}{12} \times \frac{1}{12} = 33$) inches. But as we have seen, the musical interval between सा and ती. रि. is 8 : 9 ; the pitch of ती. रि. is $\frac{8}{9}$ of सा ; so if we inverse this ratio of pitch, we get the length required. [$36 \times \frac{9}{8} = 40.5$ inches]. Thus we get 40.5 inches as the length for ती. रि. Consequently Raja Surendra Mohan Tagore's ती. रि. is flatter or कौमल than the just Major Second which we actually sing and play ; the interval also is smaller than the correct one. Similarly incorrect results might be obtained for the other notes, by following Raja Surendra Mohan Tagore's method.

15. I now proceed to show how Cap. Day and Mr. A. J. Ellis, in their attempts to find out the positions of the twenty-two Shrutees, were not successful, perhaps misguided, partly by the erroneous information of recent publications and partly by the assumption that the Hindu writers have followed or are inclined to follow the equal 'temperament' system of Europe in developing their Chromatic Scales. The lines on which Mr. Ellis tried to solve the question of the Shrutees may be seen from the following extract from his paper read before the Royal Society of Arts in 1885. Cap. Day also was similarly misled, and he follows Mr. Ellis' division. Mr. Ellis follows the lines suggested by Raja Surendra Mohan Tagore, whose methods I have already referred to. In his paper Mr. Ellis says :—

“ Now we do not know precisely what a degree is. And hence any representation of these differences with exactness is impossible. But we may obtain a tolerably approximate notion thus : suppose the fixed notes to have been those already described in the old C.

Mr. Ellis for simplicity translates Atikomal by Double flat and so on. As I have already stated this is a very loose and inaccurate rendering.

of the wire he made thirteen equal subdivisions, each being also called a Shrutee. Thus in all he got the twenty-two Shrutees. Let us now see whether according to the Raja's apportionment we get the other notes correctly. Now there are three Shrutees for ती. रि. of the Diatonic Major Scale. (Vide. रागविनोद आर्य २० and २२). According to Raja Surendra Mohan Tagore's division, three Shrutees would mean three parts out of the nine equal parts in the first quarter of the whole speaking length of the wire; the length of these three parts would come to $\frac{1}{3}$ part of the whole wire ($\frac{1}{4}$ wire divided into 9 parts, each part = $\frac{1}{4} \times \frac{1}{9} = \frac{1}{36}$; three such parts would mean = $\frac{1}{36} \times 3 = \frac{1}{12}$ part of the whole length). Thus the ती. रि. will be produced, on the $\frac{1}{12}$ part of the whole wire, according to Raja Surendra Mohan Tagore's method; i. e. ती. रि. will be produced on a length of 33 ($= \frac{3}{1} \times \frac{1}{12} = 33$) inches. But as we have seen, the musical interval between सा and ती. रि. is 8 : 9; the pitch of ती. रि. is $\frac{2}{3}$ of सा; so if we inverse this ratio of pitch, we get the length required. [$36 \times \frac{3}{8} = 32$ inches]. Thus we get 32 inches as the length for ती. रि. Consequently Raja Surendra Mohan Tagore's ती. रि. is flatter or कोमल than the just Major Second which we actually sing and play; the interval also is smaller than the correct one. Similarly incorrect results might be obtained for the other notes, by following Raja Surendra Mohan Tagore's method.

15. I now proceed to show how Cap. Day and Mr. A. J. Ellis, in their attempts to find out the positions of the twenty-two Shrutees, were not successful, perhaps misguided, partly by the erroneous information of recent publications and partly by the assumption that the Hindu writers have followed or are inclined to follow the equal 'temperament' system of Europe in developing their Chromatic Scales. The lines on which Mr. Ellis tried to solve the question of the Shrutees may be seen from the following extract from his paper read before the Royal Society of Arts in 1885. Cap. Day also was similarly misled, and he follows Mr. Ellis' division. Mr. Ellis follows the lines suggested by Raja Surendra Mohan Tagore, whose methods I have already referred to. In his paper Mr. Ellis ...

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Scale, so that C to D, F to G, and G to A, have each 204 cents, and a degree of such an interval should be a quarter of that amount, or 51 cents. The interval D to E, or A to B, has only 182 cents, and but only 3 degrees, so that each degree has 60 $\frac{2}{3}$ cents. Finally, the interval E to F, or B to C, has 112 cents, and only 2 degrees, hence one of these degrees has 56 cents. The modern Bengali division gets over the difficulty thus: The C string is divided in half, giving the Octave; the half nearest the nut is again halved giving the fourth, F. The part between the nut and F is divided into 9 equal parts, each giving a degree; and the other part from F to the Octave, is divided into 13 equal parts, each giving a degree. From these indications it is possible to calculate the value of each degree and assign the notes. In the following table I give the number of degrees and the calculation of their value on both plans, old and new, with the names of the 19 Indian notes assuming that pitch varies inversely as the length of the string as shown by the position of F and the Octave and that any errors thus arising have been corrected by ear:—

Indian Chromatic Scales.

Degrees ...	1	2	3	4	5	6	7	8
Notes ...	C	Dffl	Dfl	-	D	Efl	Efl	E
Old ...	0	51	102	153	204	264 $\frac{2}{3}$	325 $\frac{1}{3}$	386
New ...	0	49	90	15	204	316	259	374
Degrees ...	9	10	11	12	13	14	15	16
Notes ...	Esh	F	-	Fsh	Fssh	G	Afl	Afl
Old ...	442	498	549	600	651	702	753	804
New ...	435	498	543	589	637	685	736	787
Degrees ...	16	17	18	19	20	21	22	
Notes ...	Afl	...	A	Bffl	Bfl	B	Bsh	
Old ...	804	855	906	966 $\frac{2}{3}$	1027 $\frac{1}{3}$	1088	1144	
New ...	787	841	896	952	1011	1070	1135	

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6850

The only values agreeing in each are C, D, F, while new Ffl is the just Minor Third, a mere accident. The 9 degrees from C to F vary from 49 to 63 cents and then there is a sudden break, after which the 13 degrees from F to the Octave vary from 45 to 65 cents. This is the first intelligible presentment of the Indian scale which I have been able to effect. It will be seen that C, Dfl, D, Efl, E, F, Fsh, G, Afl, A, Bfl, B are represented pretty well by our equally tempered notes, but that the 7 intermediate notes Dffl, Efl, Esh, could only be

tempered on the Quarter-tone system used in Syria. Hence, in the usual transcription, these 7 notes are indented with some of the others, possibly Dffl with Dfl (not with C), Effl with Ffl (not with D), Esh with F (as usual), Fssh with Fsh (not with G), Affl with Afl (not with G), Bffl with Bfl (not with A), and Bsh with C (as usual). These comparisons necessarily injure the original character of the music, and give it a harmonisable appearance which is entirely foreign to Indian music."

16. But our method of dividing a whole tone either of 204 or 182 or 112 cents into four, three or two tones as the case may be, is not to make equal divisions, as has been supposed and done by Mr. Ellis; but the divisions are to be made in accordance with the intervals lying between two consecutive notes. For instance the interval between स and ती. रि, the first and second note of our Major Diatonic Scale is 8 : 9 with 204 cents. Now suppose we want to divide this greater interval into two smaller ones or tones. Then we introduce between स and ती. रि, a third note called को. रि. or D flat, which bears to the fundamental note स the ratio of 15 : 16, because this same ratio or musical interval already lies between the third and fourth note ग and ऋ, or between the seventh and eighth note, नि and स, of our Major Diatonic Scale. This done, the three notes स, को. रि, and ती. रि. will have the following two musical intervals lying between them. If स has 240 vibrations in a second of time, ती. रि. has 270 vibrations, the interval being 8 : 9. When को. रि. with 256 vibrations is introduced between the two notes, then the three notes स (240 vib.), को. रि. (256) and ती. रि. (270 vib.) stand to one another in the ratio of 15 : 16, and 128 : 135; having 112 and 92 cents respectively, in all making up 204 cents. But this has not been done by Mr. Ellis. He has divided the whole tone of 204 cents into four equal parts and has assigned 51 cents to each part. This is evidently incorrect and these notes obtained by equal divisions are not actually sung in practice. Similarly are obtained wrong results for other notes also.

17. Again in assigning each subdivision to a Shrutee or "degree" of the twenty-two cycle, a wrong start is generally made by some writers; because the first Shrutee or degree (though it begins from the (0) on which स is marked) is to be marked where the first

Shruti ends and not where it begins. According to the rule given in रागाविबोध of tuning strings and placing the twenty-two frets, each indicating a Shrutee, the first fret or Shruti or "degree" is to be placed *after* the zero (0) or the fixed bridge on which the whole length of the wire or the vibrating length rests, and when sounded gives the fundamental note. Accordingly the correct and proper way of assigning or marking shrutees is that noted in the Table D; and is different from that adopted by Mr. Ellis. By this process, the figure (0) comes on स or C, the first Shrutee on the second note, and the twenty-second Shrutee exactly comes on the octave स', giving 1200 cents. And according to Mr. Ellis, the twenty-second Shrutee comes on त. ती. नि. or B sharp, having 1135 cents only.

18. Similarly Mr. Ellis made another experiment. He heard Raja Ram Pal Singh playing on his सतार (Satar)—a playing instrument, at four different settings. With the aid of a tuning fork, and assisted by Mr. Hipkins, a noted musician, he observed and took down cents for each note of the Diatonic Scale at each setting and got the following results.

Scales set by Raja Ram Pal Singh.

First and Fourth setting:—

Obs. 1st.....	0	183	342	533	685	871	1074	1230
„ 4th	0	174	350	477	697	908	1070	1181
New	0	204	374	498	685	896	1070	1200
Notes.....	C	D	E	F	G	A	B	C

Second setting:—

Obs.	0	183	271	534	686	872	983	1232
New	0	204	259	498	685	896	1011	1200
Notes.....	C	D	Efl	F	G	A	Bfl	c

Third setting:—

Obs.	0	111	314	534	686	828	1017	1198
New	0	99	316	498	685	787	1011	1200
Notes.....	C	Dfl	Efl	F	G	Afl	Bfl	c

Fifth setting:—

Obs.	0	90	366	490	707	781	1080	1087
New	0	99	374	498	685	787	1070	1200
Notes.....	C	Dfl	E	F	G	Afl	B	c

These results when compared with the cents, put in my Diatonic Major table will show that the cents obtained by Mr. Ellis have not

been correct ones. The observations noted in the first line of the first setting do not tally with those of the second setting, nor those of the third setting with those of the fourth setting. Even the cents observed for the Octave (स) differ for all the four settings. But there is no wonder that such varying results were obtained. Because Mr. Ellis himself says that the setting of the frets was a "pure matter of ear and memory"; and "the frets were moved somewhat hastily and perhaps were not arranged with the accuracy that would have been attained by a professional musician."

19. I may state in brief that attempts were made in three directions or ways to solve the question of Shrutees. Messrs. Pingale and Sahasrabudde among others tried to solve the question by dividing the whole speaking length of the wire into forty-four (44) equal units, and then trying to assign the positions of the twenty-two Shrutees. The faults of their method have been explained above. Raja Surendra Mohun Tagore divided the string into two equal parts, which again were subdivided into equal parts, each containing a varying number of equal units which he designated as the Shrutees. I have already shown the erroneous nature of this method. Mr. A. J. Ellis divided each interval into as many *equal* parts as there were Shrutees *e. g.* 4, 3, or 2. I have shown above how this method too does not give a satisfactory solution. The reasons as to why Mr. Ellis could not get satisfactory results in all his experiments were: first, as he admits, the original treatises on Hindu Music were not accessible to him. Secondly, the experiments were made on fretted instruments. In these instruments, the pressing of the wire or string down to the fret increases the tension, thereby increasing the pitch. The height of strings above the frets in different instruments varies largely, say from 4 to 6 millimetres. Again in playing the same notes on different occasions, the same performer is likely to commit mistakes on account of defect of ear or want of proficiency. And, as is admitted by Mr. Ellis himself, "it is exceedingly difficult to determine the minute differences of pitch between notes with qualities of tones so different as those of plucked strings and tuning forks."

20. Now it may be asked that the श्रुति (Shrutees) in the table of 22 Chromatic notes or the Shrutee Scale (Table D) do not apparently correspond to those assigned for each of the 7 notes

in the Diatonic Major Scale. This point is cleared thus. As explained by Sanskrit writers a Shrutee is any audible musical note given by plucking the wire against the bridge; or to speak in terms of the scientist of the West, Shrutee is the smallest musical interval, lying between any two consecutive notes of the musical scale. I may make myself clear by giving an example. The musical interval between स and ती. रि. of the Diatonic Major Scale (of eight notes including the octave) is 8:9. This interval was first divided into three smaller ones, each being called a Shrutee. The author of रागत्रिबोध first laid down that that ती. रि. has three Shrutees, But for developing this Diatonic scale into the Chromatic scale of twelve or twenty-two notes, it was also laid down that स and प are to be kept unchanged (अविकृत). Therefore the eight Shrutees of स and प (four for each) had to be distributed among the other notes, after retaining one for each (one for स and one for प). Thus to distribute the remaining six Shrutees among the other notes, it was necessary to divide the interval 8:9 between स and ती. रि. into four विकृत स्वर, each called a Shrutee. Under these circumstances it will be easily seen that a Shrutee is not a *unit* of measurement, as has been supposed to be the case by several writers; but it is an interval lying between any two consecutive notes, and as such is liable to be subdivided into as many smaller intervals as there may be विकृत स्वर, or modifications of tones. Shrutees may be more than twenty-two also, this number being the one generally accepted, some Sanskrit authors recognising 42, some 66 and some saying that they are innumerable.

21. It will thus be seen that in forming the Chromatic Scale of twenty-two Shrutees, the same method of introducing smaller ratios or intervals is observed, as that pursued in forming the scale of twelve notes. The rule of perfect concord on which Sanskrit writers put so much emphasis, has been strictly observed in all the scales. It will also be clear how the Chromatic scale of twelve notes has been formed out of the Diatonic scale of seven notes, and how the scale of 22 notes or the Shrutee scale has been worked out from that of twelve notes. I have already explained the methods which the Sanskrit writers have adopted for evolving higher and finer scales. It is to be noted that these scales which are worked

out strictly on the lines laid down by our Sanskrit authors are constructed on a thoroughly scientific basis ; and they fully (through their intervals) satisfy the test of the system of cents adopted by Mr. A. J. Ellis. The theory of the स्वरसप्तक or Diatonic Major scale has already been propounded above. From all this it will be evident that the Sanskrit writers were fully cognisant of the laws of the constitution of musical sound, which have been approved of by modern science ; that they worked out their scales not " arbitrarily " but on definite and regular fixed laws ; and that in formulating their scales they were led not by " artificial " ideas, and were guided not by " capricious " suppositions, but proceeded on precise rules and principles.

22. By means of the Diachord and these tables which have been worked out from Sanskrit writers, the Musical Scale can be determined with mathematical precision. The Diachord with its moving bridge gives us an accurate means of determining the several notes correctly ; and the notes of the instrumentalist or vocalist can be tested by referring them to those produced on the Diachord. Like the tuning forks of the West which are used for testing the correctness of the notes, the Diachord with its moving bridge serves us the same purpose. The ear, which at present chiefly guides the musician—instrumentalist or vocalist—is not always an infallible test of the correctness and justness of the notes ; it is liable to vary in its capacity of adjudgment. Hence the great importance of the Diachord.

23. The experiments which I made with the Diachord, were conducted with the assistance of Prof. Abdul Kareem, an expert professional vocalist of renown. The results of the experiments which I have been making for the last few years, have been verified by him. And it is no small satisfaction to me, and I believe, as well as to the public, that the results of my study of the theory of the Hindu Musical Scale as propounded by the old Sanskrit writers have been approved of and amply corroborated by eminent professional artistes like Prof. Abdul Kareem. It might be stated here that but for the kind help and open-hearted assistance of the Professor, I should not have been able to lay these few ideas before the public. I cannot but here express my heartfelt obligations to the works of modern

Indian writers like Messrs. Kunte, Pingale, Sahasrabuddhe, Banhatti, Chinna Swami Mudliar, and Raja Surendra Mohun Tagore among others ; and also to the works of European writers like Sir William Jones, Capt. Day, Messrs. Bosanquet and A. J. Ellis, for the valuable light of information and criticism which they throw upon the subject. To the study of Hindu Music which these writers made and to their labours for regenerating and encouraging this Art of Arts, I humbly and respectfully add my share, infinitesimally small though it is. As endeavours in this direction are carried and pursued further, it is quite possible that more light will be thrown on the subject ; and perhaps the results which I have obtained at present might undergo modification. I stand open to correction.

24. I cannot conclude without making an appeal to the public in the interests of this Art of Music. At present, broadly speaking, the Art is confined to two classes, professional Musicians—Vocalists or Instrumentalists—and the operatic (संगीत) stage. And if the excellence of the Art is to be found anywhere, it must be admitted to exist among the Professional Musicians only. All credit is due to them, because in spite of the absence of material encouragement in recent times, they alone have still preserved and protected this ancient and richly developed Art from total extinction. Our Hindoo religion, which is so comprehensive in its relation to life as to hardly leave any subject outside the sphere of its influence, has done not a little, in fact it has done the utmost, by means of the numerous rites and ceremonials which embody music as a part of their programme, to preserve, cultivate and develop this Art. The great stimulus which Institutions like the Gayan Samaj of Poona and other centres, and the Gandharya Maha Vidyalaya of Lahore (the Academy of Indian Music, conducted by Pandit Vishnu Digamber Paluskar), have given to the study of this Art by creating a wide interest among the people, must be candidly acknowledged. All these attempts are surely commendable, but looking to the steady and slow decline of this Art in recent times, it must be recognised that they are insufficient for the purpose in view. The blind imitation of the Westerns which was the besetting sin of our educated people about 50 years ago, has had its evil effects on Music also as on other spheres of activity. No other

institution succumbed to the passion so completely as our Dramatic Stage. The harmonium and piano of the West soon took the place of the Veenā, Bin and the Sarangi and the musical precision and rich melody of old soon gave place to imperfect and graceless music. Instruments of the harmonium family with fixed keys which reign supreme at present on our stage, are based on the *European Temperate Scale*, which is admitted by European musicians themselves to be a defective scale. As observed by Professor Blaserna, "it is an incorrect scale. It has destroyed many delicacies and has given to music, founded on simple and exact laws, a character of almost coarse approximation." These are instruments with fixed keys, they restrict a musician by compelling him to choose a note out of a fixed scale, and that too arranged on an *approximation to natural tones*. Again the notes on the piano or harmonium die away rapidly and do not give rise to overtones which are the essentials of rich and good music. Aroha (ascent), Avaroha (descent), Murchchhana (a quarter-tone), Mends, or Ghasits—all these are necessary for the proper execution of a Raga or Ragini; and in the very nature of things, they cannot be had on the harmonium or piano. Yet our musical pieces which are composed in accordance with the rules of Indian Music, are sung on the stage in accompaniment with these instruments! For example, the singer of दशरि कानडा (a Raga), obtains on the harmonium not the counterpart of his Raga, but quite a different tune; and the result is the creation of imperfect music and ludicrous incongruity. And yet, it is this incongruity which is enacted and tolerated on our dramatic stage, night after night! As Professor Blaserna rightly observes, "music founded on the temperate scale must be considered as imperfect music and far below our musical sensibility and aspirations. That it is endured and even thought beautiful only shews that our ears have been systematically falsified from infancy."* How truly do these remarks hold good in our case, may

* Hon. Mr. Muir Mackenzie explained to me that vocal music and music on instruments of the violin family is sung and played in the exact scale by connoisseurs only in Europe. But I would add that the *tempered* scale has been adopted in Europe to suit the exigencies of instruments with fixed keys. Its advantages for the European system which is dependent on transposition and unlimited modulation from one key to another are felt to far outweigh its disadvantages, and there is very little probability of a return being made to the natural scale in the near future in Europe. At the same time Indian Music which is not dependent on extensive modulation has no need whatever for a *tempered* scale.

be easily seen from the impatience which the theatre-going audience shows towards scientific and correct Indian music. The harmonium not only vitiates the taste of the audience, but it is bound to falsify the ear of the stage-singer himself. A good and expert professional singer will never tolerate the harmonium as an accompaniment to his performance. It must also be borne in mind that it is the stringed instrument that forms the nearest approach to the human voice. The Honourable Sir J. W. Muir-Mackenzie, late Member of Council to the Bombay Government, who was a keen connoisseur of music, in his speech delivered on the occasion of the Prize Distribution Ceremony of the Poona Gayan Samaj, observes: "I don't appreciate the portable harmoniums much talked of by the Secretary from the Swadeshi point of view as they were not in harmony with Indian Music." While some Europeans are themselves condemning the adoption of the temperate scale—on which are based instruments of the harmonium family—as being productive of evil results and destroying the purity, fineness, and delicacy of music, we are, strangely enough, engaged in reproducing and perpetuating those very defects in India and impairing the high nature of our music! It is high time that our eyes were opened to the mischief being constantly done by the introduction and use of instruments based on the European temperate scale. The stage is only a type of cases where the evil is spreading and manifesting itself prominently. The remedy must be applied externally to the part most affected, and internally to the root cause of the disease. The stage must be freed from the passion for the harmonium, and the people must be awakened to encourage and foster the art of Indian Music. All those interested in the re-generation, preservation and development of this Art of Arts, must labor for the cause and render help by the means in their power.

APPENDIX A.

A Note by Mr. Nilkanth Vinayak Chhatre, B. A., L. C. E.
late of Bombay Educational Department.

R. B. Deval, retired Deputy Collector, has laid the musical world under deep obligations by placing before them in the accompanying brochure all the facts and figures regarding the evolution of the principal tones and intertones of the Hindu Musical scale, as sung at the present day by eminent masters of the science and art of Hindu Music (Vide Tables A, B, C, & D). The evolution is not capricious but based on rules given in old Sanskrit works on Hindu Music, such as Sangit-Ratnakara, Raga-vibodha &c., The rules are few and simple—

- १ मेरुश्रितुर्नृत्तं नीरवे सः षड्जः अभिव्यज्यते ।
- २ मध्यस्थानस्थः मध्यमः । उभयोः षड्जयोर्मध्ये मध्यमं स्वरमाचरेत् ।
- ३ द्वाविंशीत्यः षड्जः द्विगुणसमः ।
- ४ त्रिभागात्मकवीणायां पञ्चमस्यास्तदग्निमे ।
- ५ सप्तमं मुख्याः संवादिनः स्वरः ।
- ६ मेरुगतं स्वयंभू स्वरपङ्क्तिं प्रामाण्येन ।
- ७ तन्त्रीतनुस्वरो ज्ञेयस्तद्द्वैत्यव्यस्तमानतः ।
तनुस्थौल्येऽपि त्रिज्ञेयस्तनुसौक्ष्म्येऽप्ययं विधिः ।
- ८ षड्जपञ्चमयोरविकृतत्वात् ।
- ९ स्वरसोपान परंपरा ।

How these simple rules are used in the evolution of the musical scale, is fully explained in pages 9 to 23 and the tables A, B, C, & D.† How anxious the people were to give their Musical scale the sanction of Nature is seen by their adopting the third note (E) of 300 vibrations in place of 303½ vibrations, for this was evolved as the 5th Harmonic.

For some reason or other the efforts of well intentioned enquirers both European and Native to get at the correct idea and measure of the notes of the Hindu scale had hitherto proved futile and unsatisfactory. (See paras 14, 15 &c.) Mr. Deval's claim to admiration lies in grasping the whole difficult situation and in ingeniously applying the Sanskrit rules in a systematic manner to the evolution of the Hindu scale of the principal 7 (8 including the octave) notes and in suitably interposing 15 additional notes into the intervals between them and thus evolving 22 notes (23 including the octave) corresponding to the long known 22

† Vide also 'सप्तस्वर व श्रुति' by Mr. N. V. Chhatre B. A., L. C. E. p. 7.

Shrutees of the Hindu Musical scale. That the notes so evolved are correct and are the same as those used in the several Ragas and Ragines at the present day, is borne out by the testimony of artists like Professor Abdul Karim &c. The correct idea of a Shruti is that it is not a unit of measurement, but it is an interval lying between any two consecutive notes (See paras 20, 21). Each such interval (Shruti) is distinguished by a distinct name and is thought to appeal to certain emotions. The verses of the Vedas which are sung in honour of certain Vedic deities at certain sacrifices in India were characterized by the introduction of suitable distinct Shrutis as leading notes (Sahasrabuddhe-Sangitsar Part 1 Page 54).

The Diachord is the instrument on which the intervals or the several notes are evolved and marked. The Diachord is useful for testing the accuracy of a musical note and one of the pattern of Mr. Deval which is simple in construction, may very profitably be supplied to each college or class wherever Hindu music is taught systematically.

It will be interesting to find out and compare the notes which were used in musical pieces sung at sacrifices in old Hindusthan, Greece and Rome and in modern Church services. The field is wide and full of hope and may lead to results as important as those of Comparative Philology.

The essential basis of music is melody and this is contained admittedly in the Hindu scale to its full extent. This has been the main charm of the Hindu system of music for thousands of years in the past and will continue to remain so for a number of years in the future, if the readiness of the people to use harmoniums and other tempered instruments for teaching the gamut is checked betimes by all the civilized world.

The 22 Shrutis which are used in the musical pieces of Hindus have now been mathematically calculated and fixed by Mr. Deval and there is no doubt that his Diachord will serve as a useful guide in constructing a harmonium or tuning a pianoforte to the natural and just scale of Hindu music.

The rhythmic movement of successive notes which is the soul of Hindu music or natural scale has a charm peculiar to itself. This is melody. It is free from trammels of consonant chords and harmonic combinations which have so great a charm for the European ear. Hindu Music lacks this. Hindu music is, however, rich in the wealth of a more pliant melody which has the privilege of appealing touchingly to the emotions.

Each Shruti is allotted to a peculiar emotion as its name रग, रस or the like clearly shows. If Hindu Music wants harmony European music, to our ears, lacks melody. Here is the case of a blind man and a lame man so aptly illustrated in Æsop's Fables. Let us assist each other. Now that Mr. Deval has evolved the Shruti scale, musical instruments may be tuned accordingly; and these will give Europeans a correct idea of Hindu musical charm and a happy way opened out for a suitable exchange of musical wealth by one nation to the other. The field of Hindu music is very wide and to appreciate it correctly and completely one must hear the professors of the art. The charms of menda (मंड) and ghasit (घसित) are realized only when they are properly rendered on stringed and wind instruments. Keyed musical instruments howsoever perfect in their construction are by their very nature unfit for such execution. These मंड and घसित should be heard by lovers of music from the masters of the art. They have spent their lives upon them. Their race is fast dying out for want of support. Let it be mentioned however to the credit of the Hindu public and the Native States in India that they have been and are making efforts to preserve this Art of Arts from decay and final extinction by holding annual gatherings of musicians and entertaining the services of those who are the best among them. I give below a list of famous professors as far as my knowledge goes and request the readers of Mr. Deval's pamphlet to extend the list by suggesting to him the names of other people they may know of.

- | | |
|--|-----------------------|
| 1 Miya Aladiya Khan | } of Kolhapur Durbar. |
| 2 Miya Haidar Baksh | |
| 3 Antoba Sadhale, pupil of Kudhosing. | |
| 4 Balkrishnaboa of Ichalkaranji. | |
| 5 Bhayyasaheb Joshi. | |
| 6 Vishnupant Joshi pupil of Nasarkhan of Baroda. | |
| 7 Bhaskarbawa Bakhale pupil of Faiz Mahammad. | |
| 8 Rahimatkhani son of Haddukhan. | |
| 9 Gokhale brothers of Miraj and Kolhapur Darbar. | |
| 10 Sheshanna of Mysore. | |
| 11 Inayat Hussain of Hyderabad Deccan. | |
| 12 Parasahab of Calcutta. | |
| 13 Indatkhani of Gwalior. | |
| 14 Professor Abdul Karim of the Deccan. | |
| 15 Muradkhani Binkar of Gwalior. | |

Before taking leave of my readers I beg to suggest that every effort should be made by Europeans and Natives to preserve this dying Art by

suitable encouragement, for this is one of the platforms on which all persons of whatever caste and position and shades of thought may meet as equals and share the pleasure of company without losing their individuality.

I beg to close the introduction by congratulating Mr. Deval again for his ingenious evolution of the Hindu Musical Scale and the 22 Shrutis.

APPENDIX B.

'The essential basis of music,' as Helmholtz rightly observes, 'is melody.' And, as has been observed by my learned friend Mr. Chhatre in his note to this brochure, this (melody) has been the main charm of the Hindu system of music. The same opinion has been distinctly expressed by many European Scientists and Musicians of note; and I have added in this appendix extracts from their writings on the importance of melody in music.

"The object of this introduction will be gained if we, for a little while, allow ourselves to forget the glory and splendour of our modern harmony, in favour of those melodic systems which once satisfied the great nations of classical antiquity and still content those hoary civilizations of the East which preserve so much that is really ancient in their present daily life. Capt. Day shows an interesting resemblance between the leading modes of old Greece and Asia Minor and certain favourite modes of the Hindus. There is no sure evidence of an intimate musical connection between these countries and India, a few scattered references in classical writers excepted, but the relationship of sister Aryan languages may have been paralleled by a relationship of musical types sufficient to justify a theory of descent instead of one of imitation."

Hipkin's Introduction to Capt. Day's Music of Southern India, P. 11.

"This is the musical scale which is established in nature—the most pleasing to all ears and the most accordant with the philosophy of music. This scale in its exact proportions is also the most natural and easy for the human voice—that most wonderful of all musical instruments—in any key. The violin too can give accurate intonation. But the ordinary organ and other keyed instruments do not produce this scale of nature. The voice in exact tune. It may be easily seen that if the scale is made perfectly correct in one key some of the notes must of necessity be incorrect, by a degree or two in all the other keys. They

are therefore called imperfect. Mr. Graham, in his 'Theory and Practice of Musical Compositions' shows the great injustice and the great injury to music, which arises from the frequent endeavour to form the voice—a perfect instrument—according to the false intonation of such instruments as these. General Thompson says: 'It may be hoped that time is approaching when neither singer nor violinist will be tolerant of a tempered instrument. Singers sing to the pianoforte because they had bad ears; and they have bad ears because they sing to the pianoforte.' ” John Curwen: A Grammar of Vocal Music, 26th Edition, page 40.

“ But I consider it a mistake to make the theory of consonance the essential foundation of the theory of music, and I had thought this opinion was clearly enough expressed in my book. The essential basis of Music is melody. Harmony has become to Western Europeans during the last three centuries an essential, and to our present taste, indispensable means of strengthening melodic relations; but finely developed music existed for thousands of years and still exists in ultra-European nations without any harmony at all.” Helmholtz 'Sensations of Tone', Author's Preface, 3rd Edition.

“ The proper succession of single musical sounds is called melody. Some study of melody is absolutely essential to a good singer.” Dr. John Curwen 'A Grammar of Vocal Music' 26th Edition.

“ The greater freedom in musical intervals, melodic systems allow, must be reckoned as compensating in some measure for the want of harmonic combinations of which our European music has such inexhaustible wealth.” Hipkin's Introduction to Capt. Day's Music of Southern India, Pp. 11, 12.

“ Since a sweet note is already a harmony, the influence of the recognized musical concords is not something absolutely new but the extension of the same harmonising process.” Prof. Bain—'Harmony.'



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